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Becker et al.

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(54) **WELD TRAINING SIMULATIONS USING MOBILE DEVICES, MODULAR WORKPIECES, AND SIMULATED WELDING EQUIPMENT**

(58) **Field of Classification Search**
CPC G09B 19/00; G09B 19/24; B23K 9/095; B23K 9/10
See application file for complete search history.

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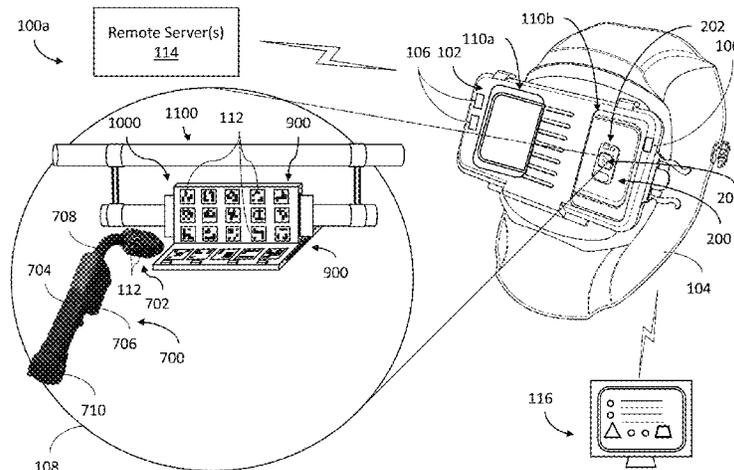
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(57) **ABSTRACT**

Systems for simulating joining operations, such as welding, are disclosed. In some examples, a system may use a mobile device for conducting welding simulations, such as for purposes of training. In some examples, the system may additionally, or alternatively, use modular workpieces. In some examples, the system may additionally, or alternatively, conduct the welding simulation based on one or more selected pieces of welding equipment.

20 Claims, 23 Drawing Sheets



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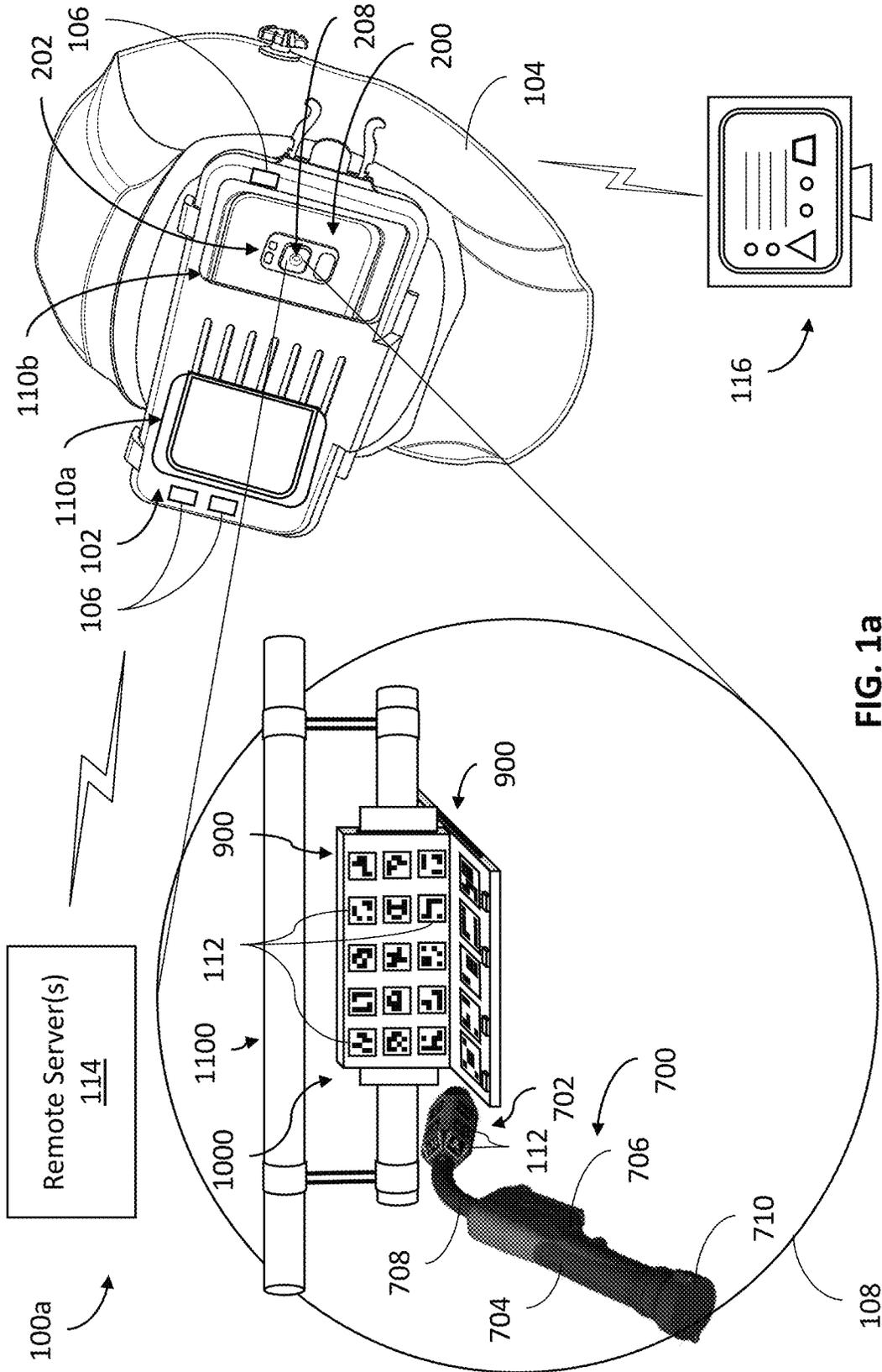
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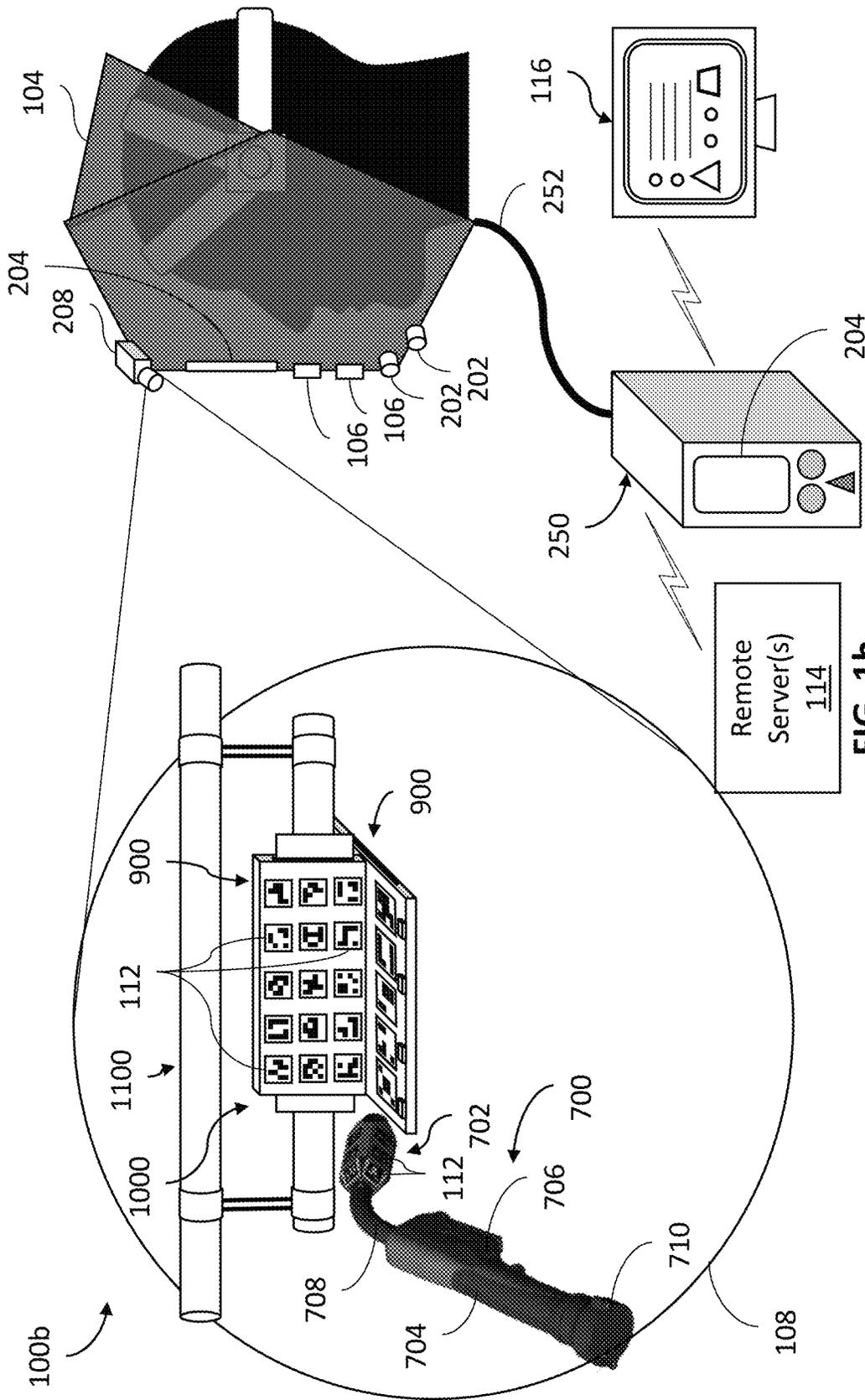


FIG. 1b

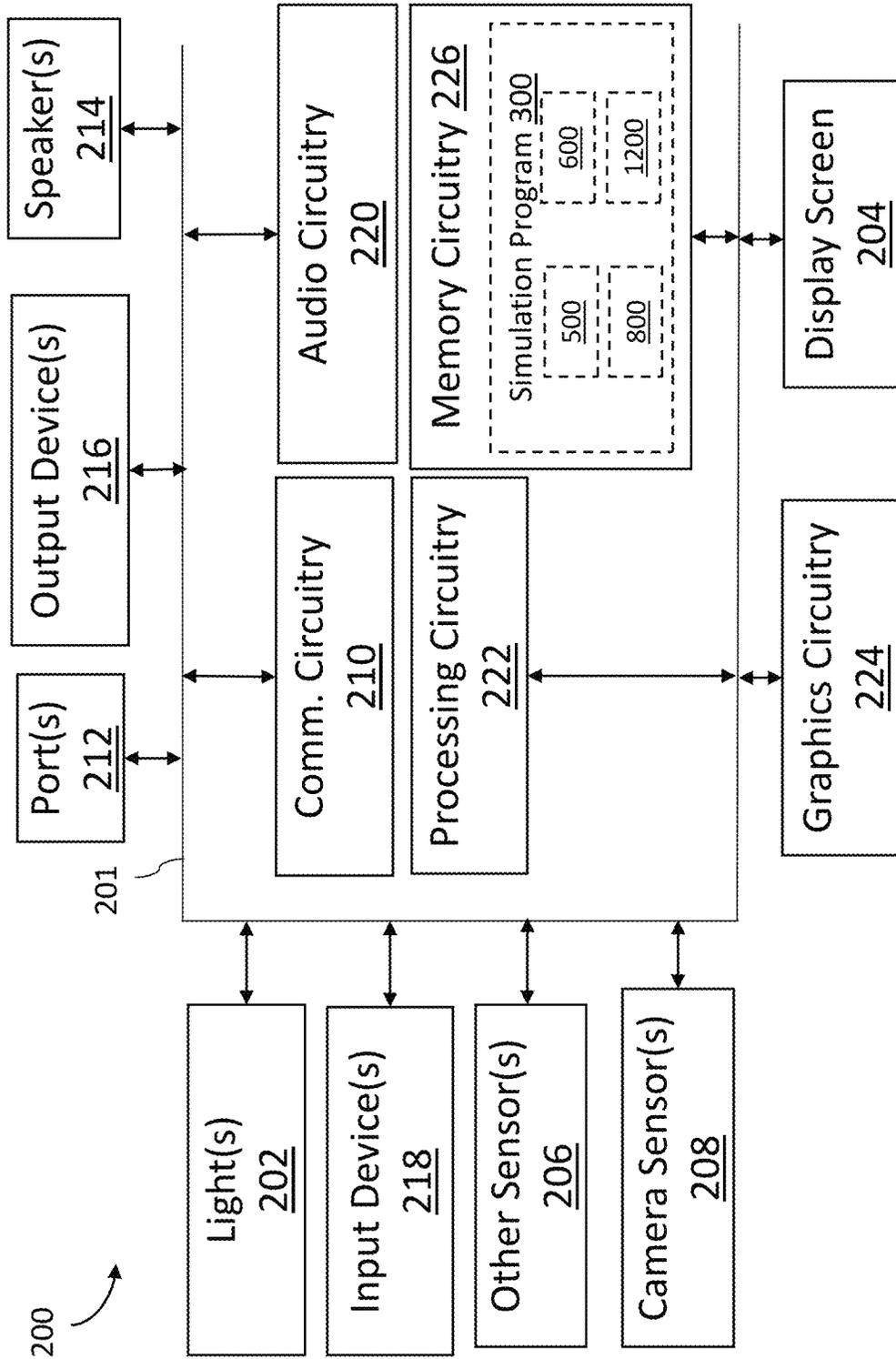


FIG. 2

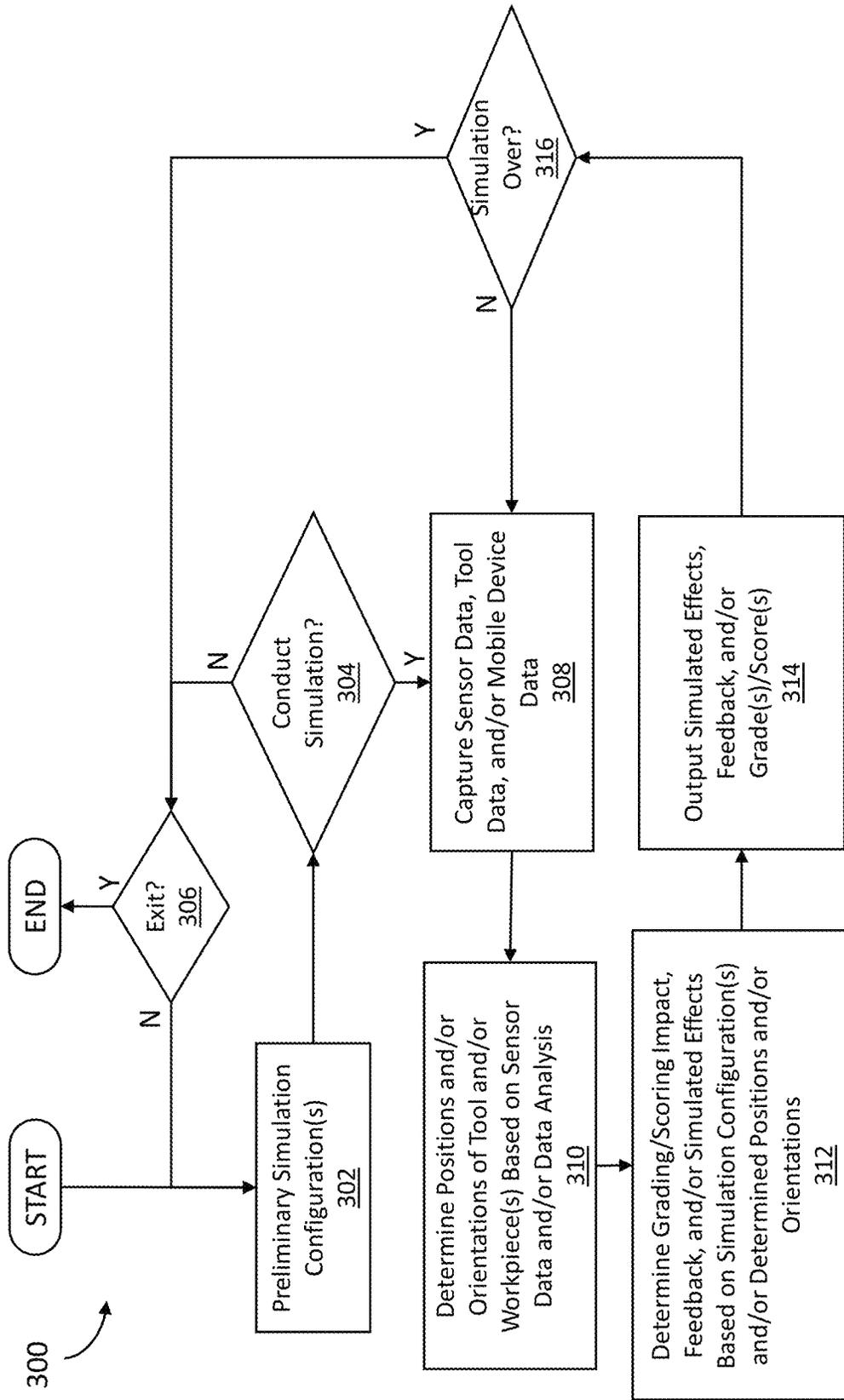


FIG. 3

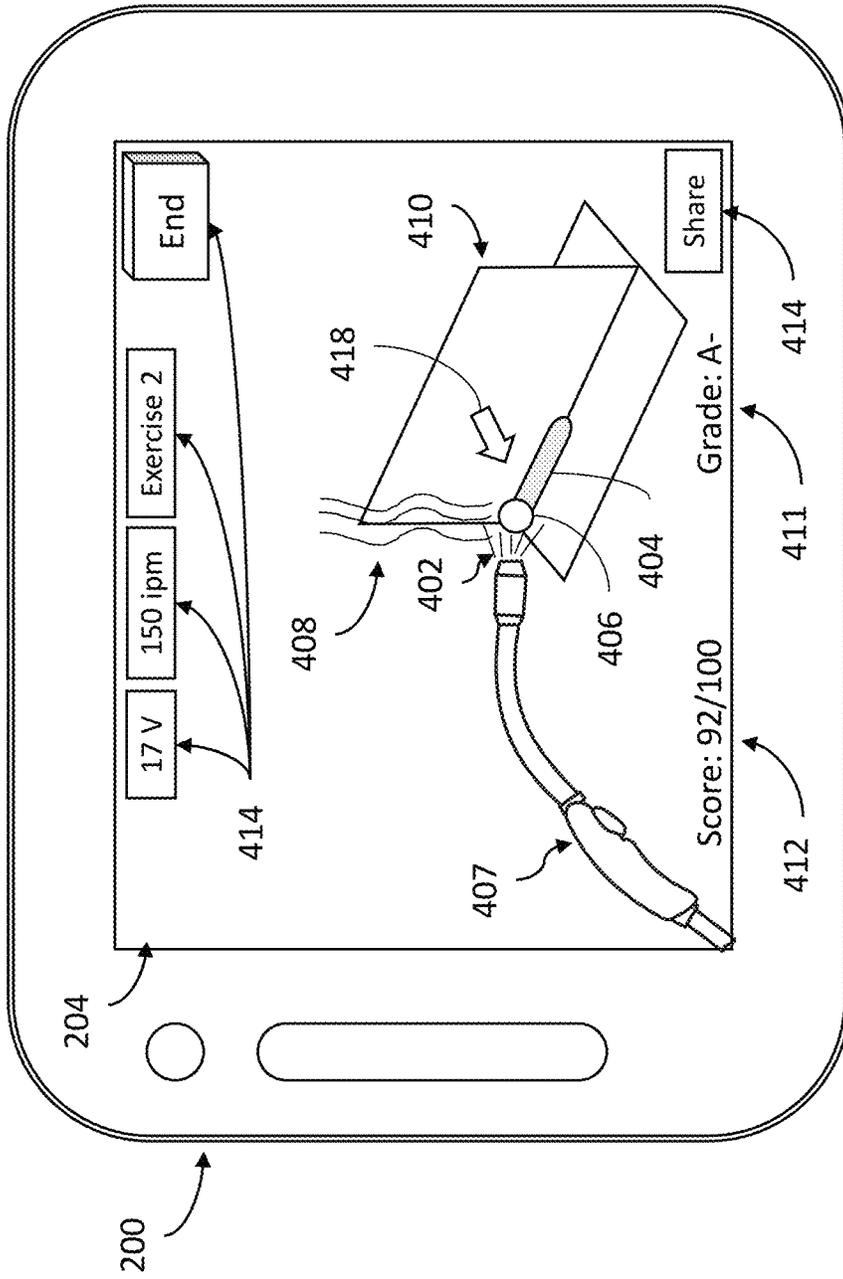


FIG. 4a

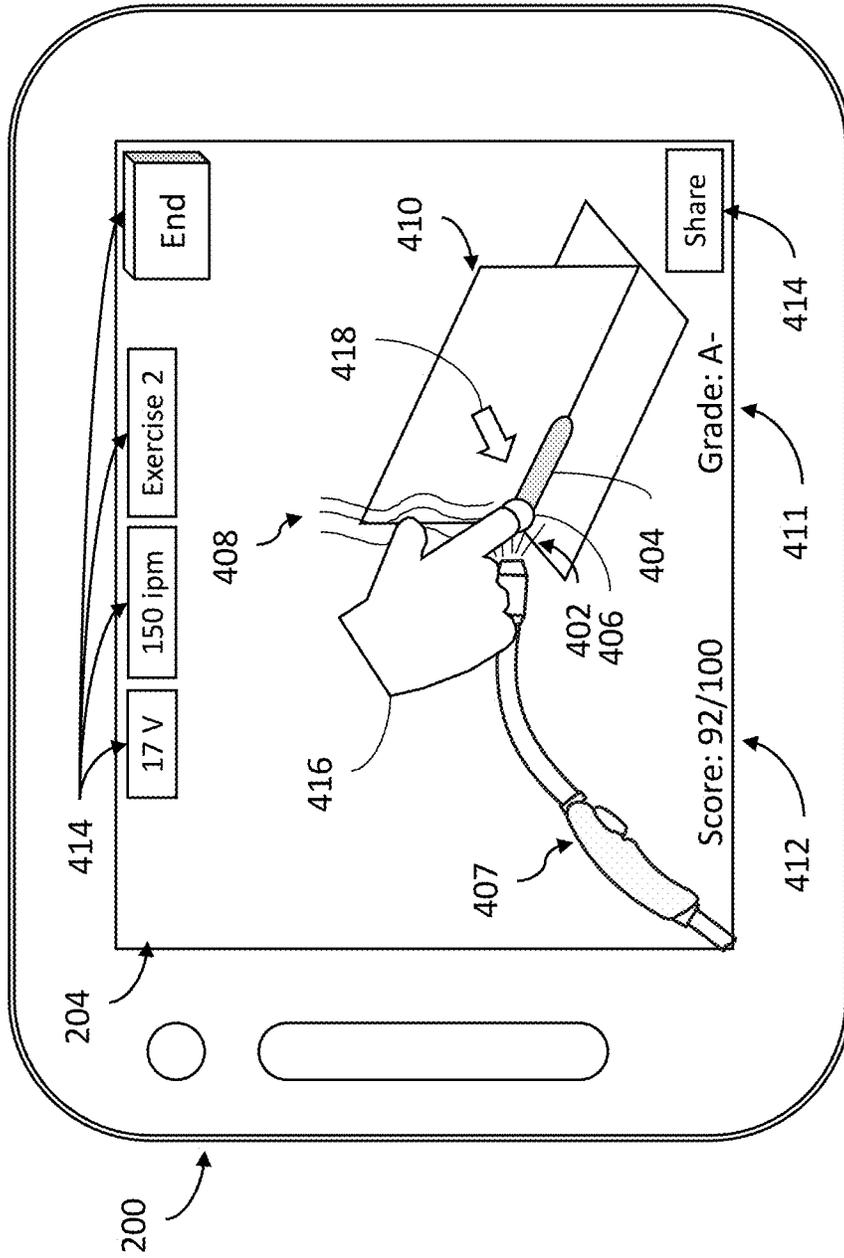


FIG. 4b

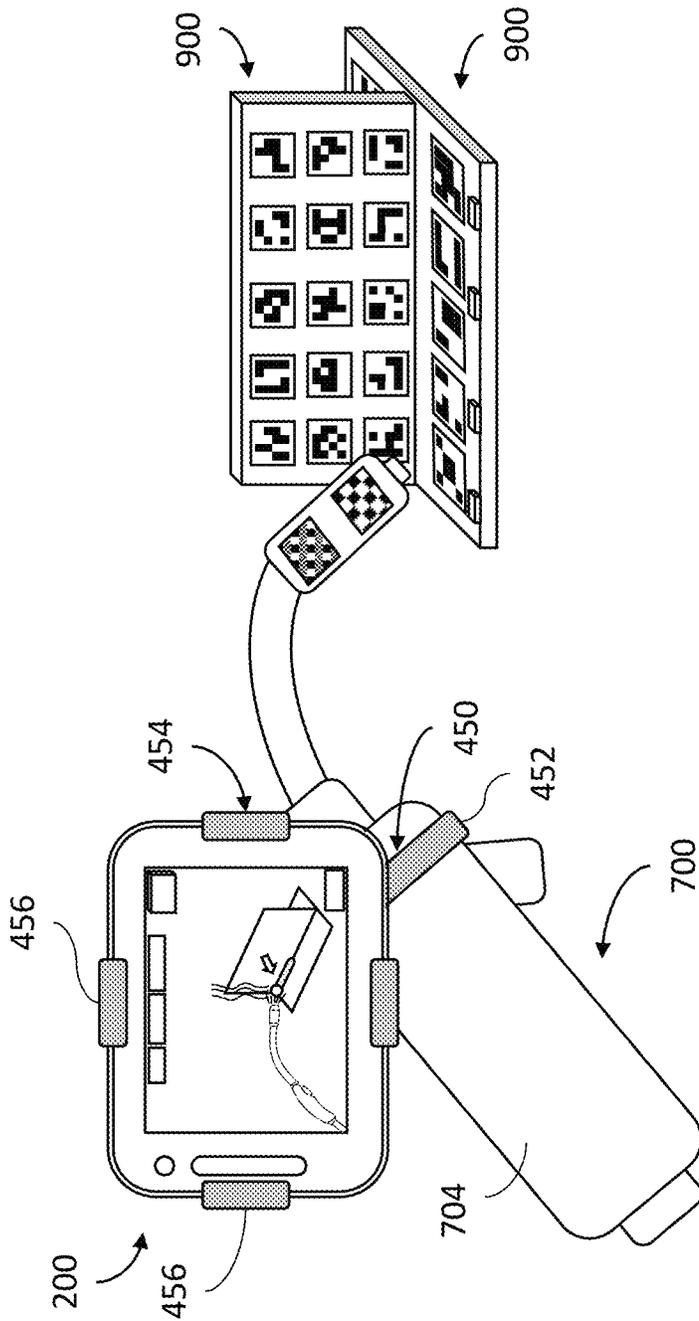


FIG. 4c

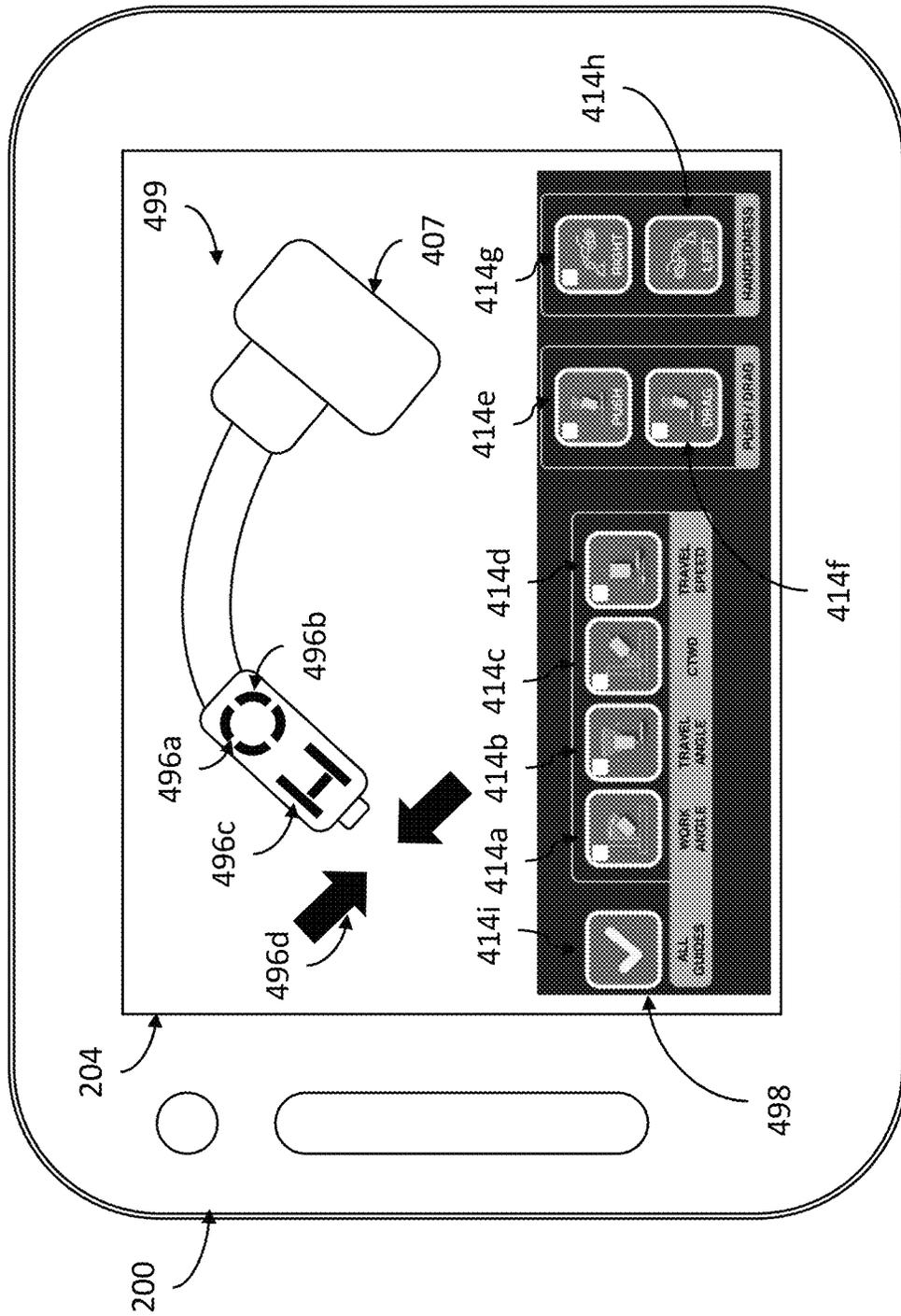


FIG. 4d

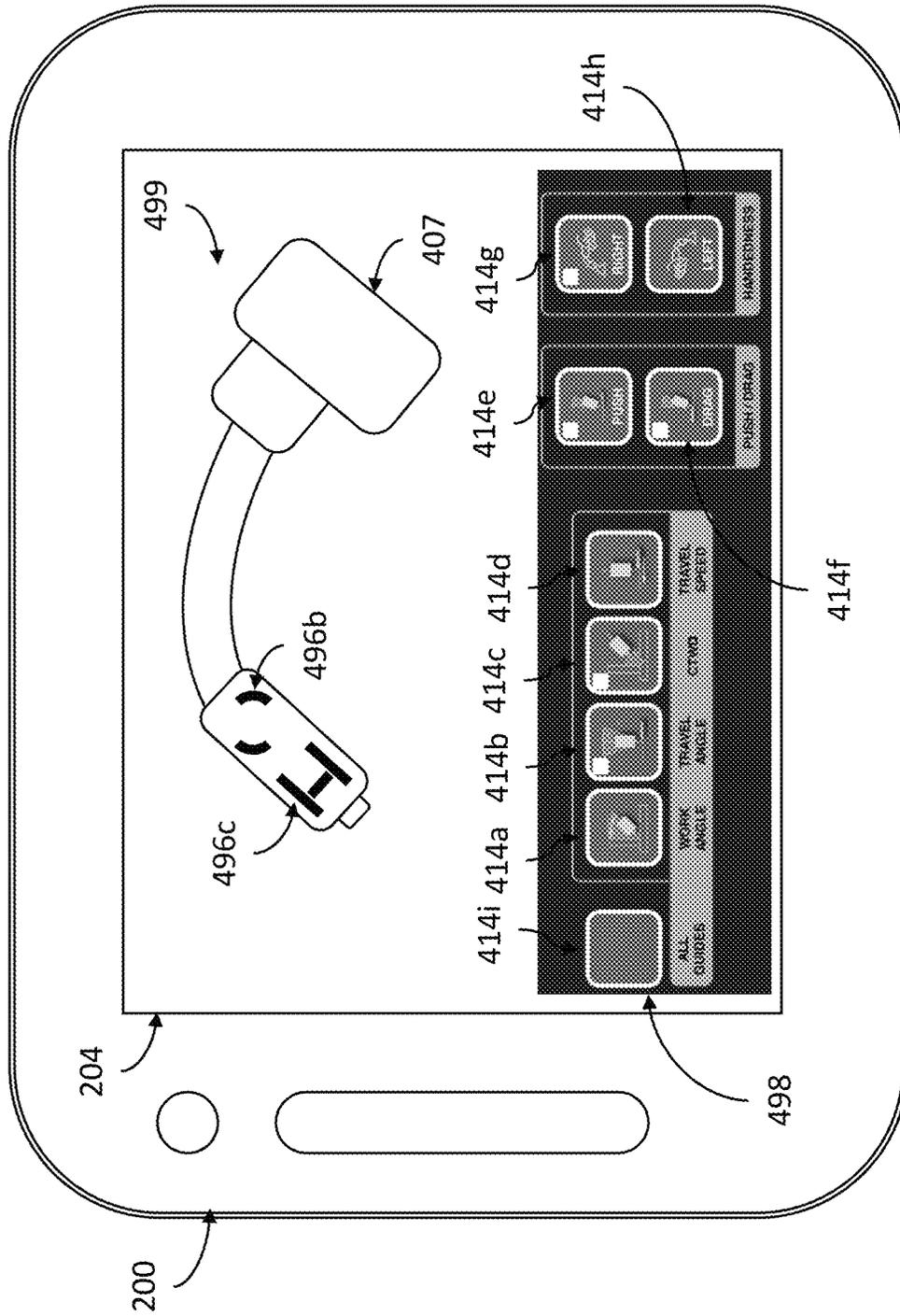


FIG. 4e

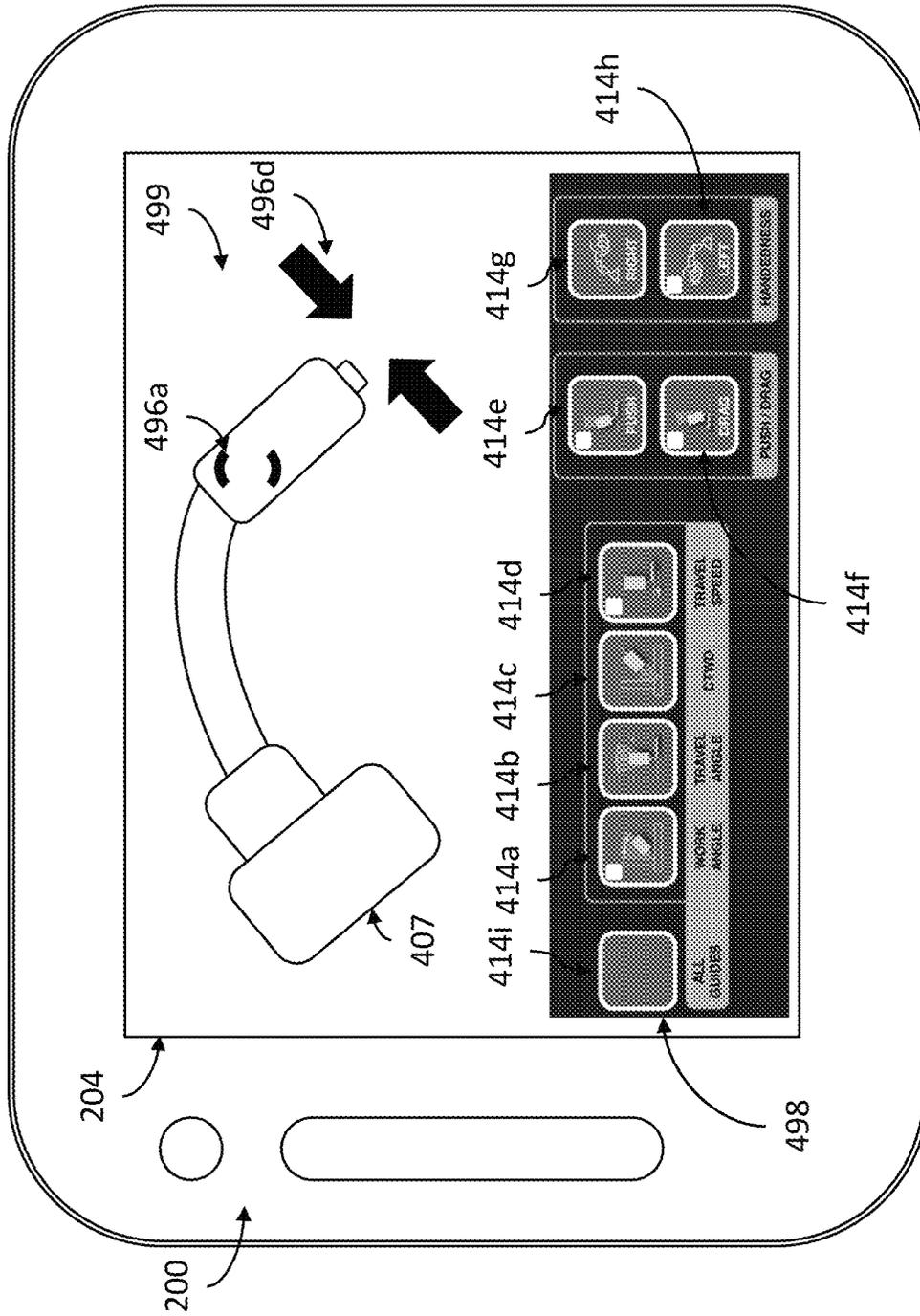


FIG. 4f

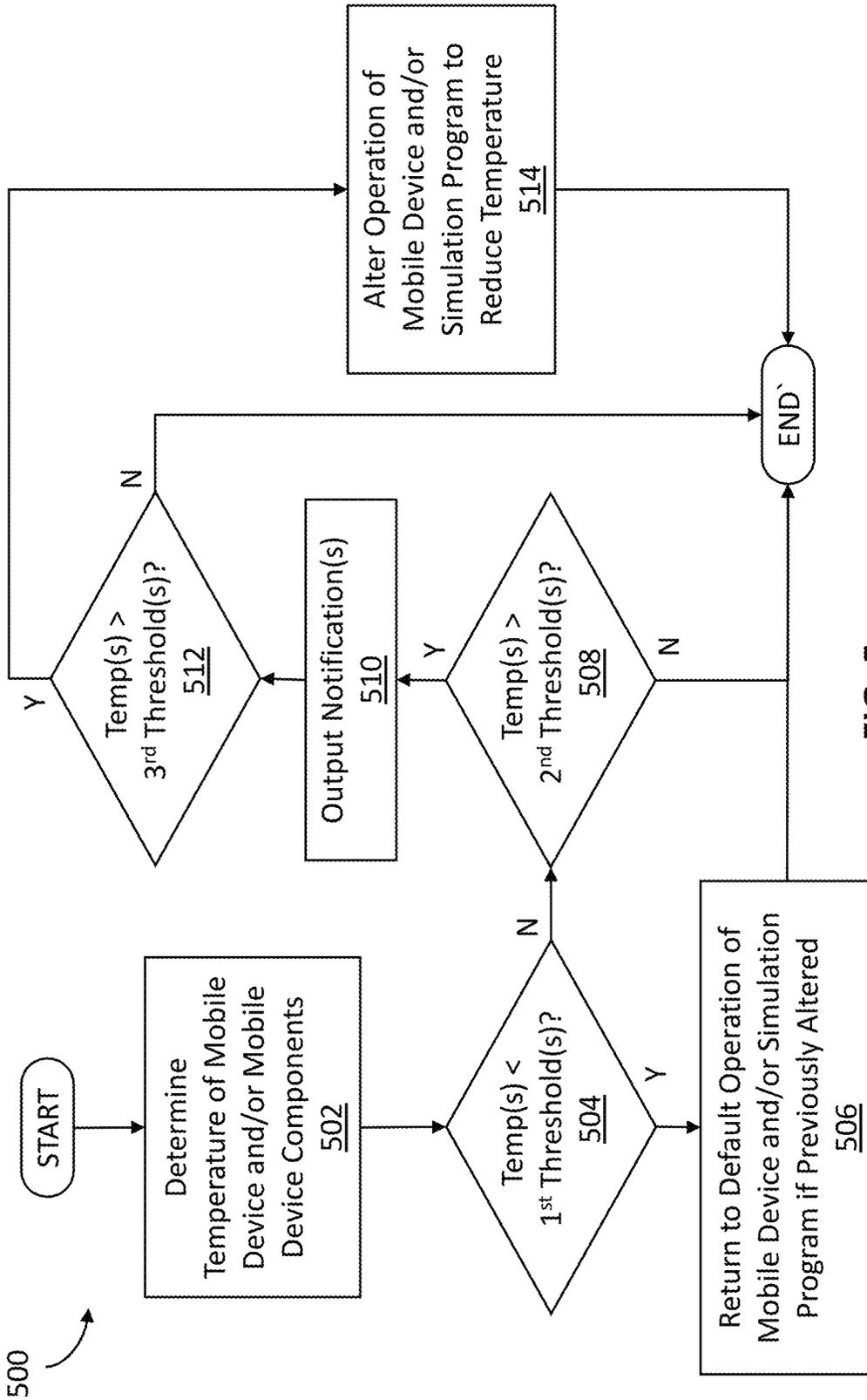


FIG. 5

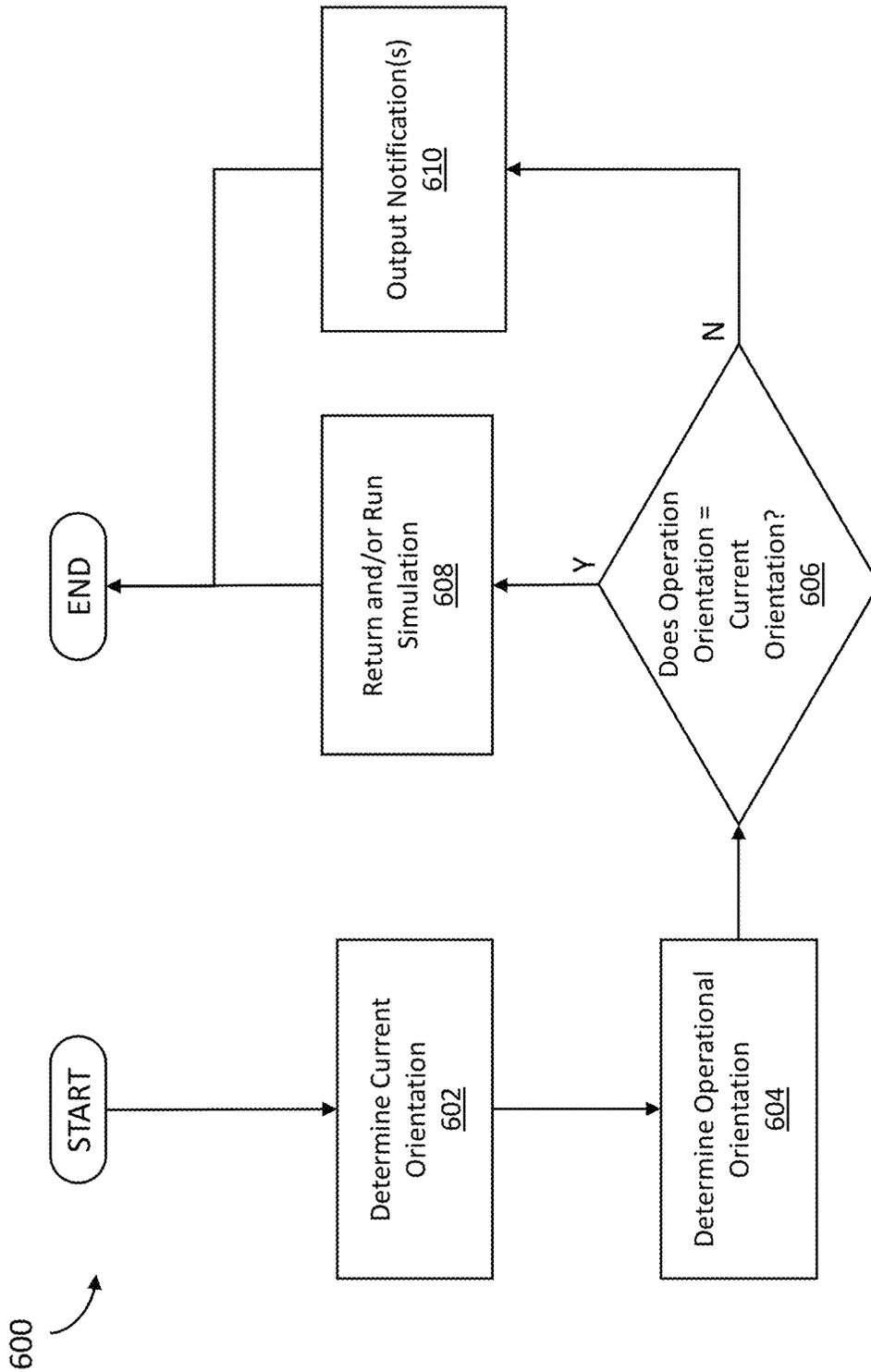


FIG. 6

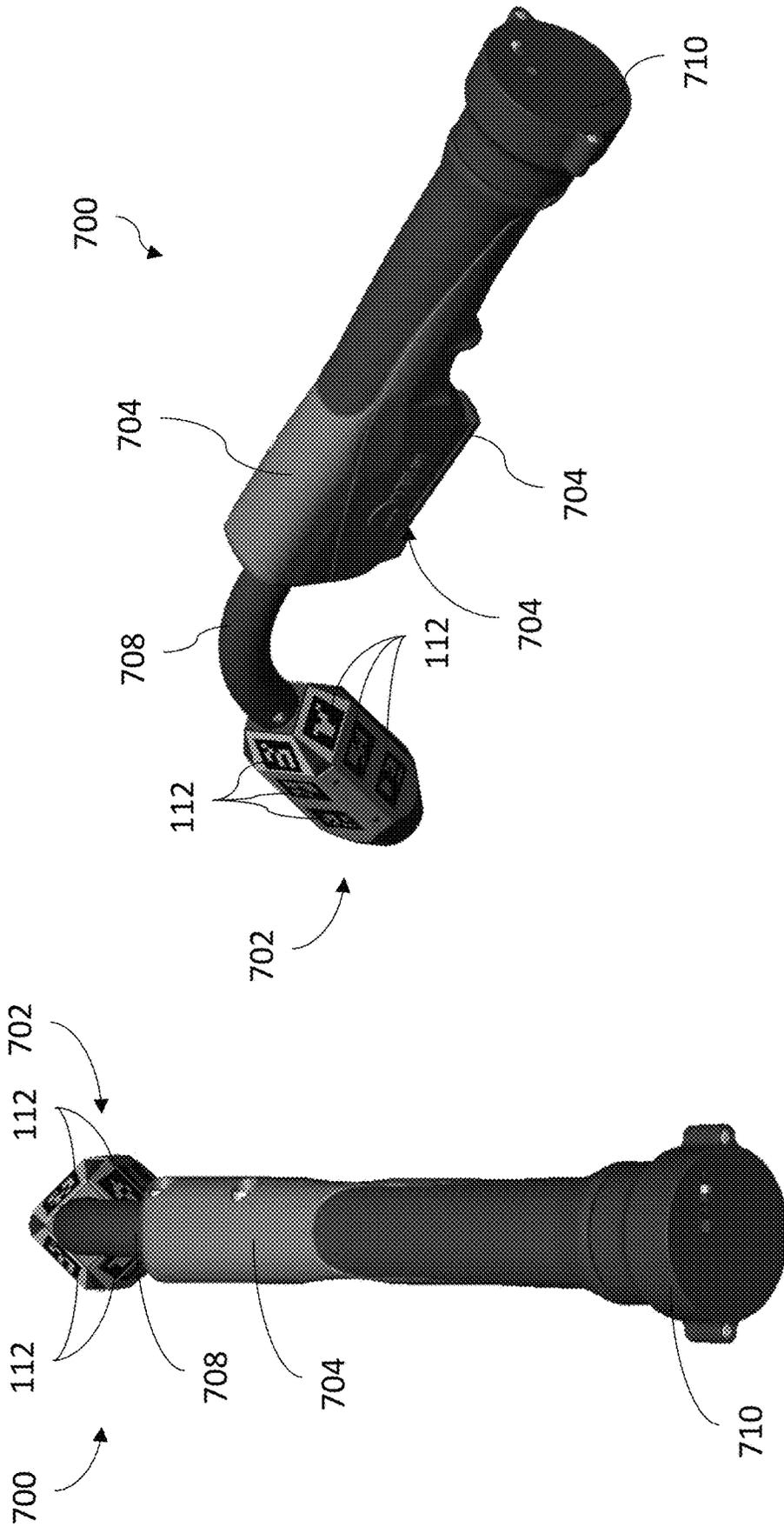


FIG. 7b

FIG. 7a

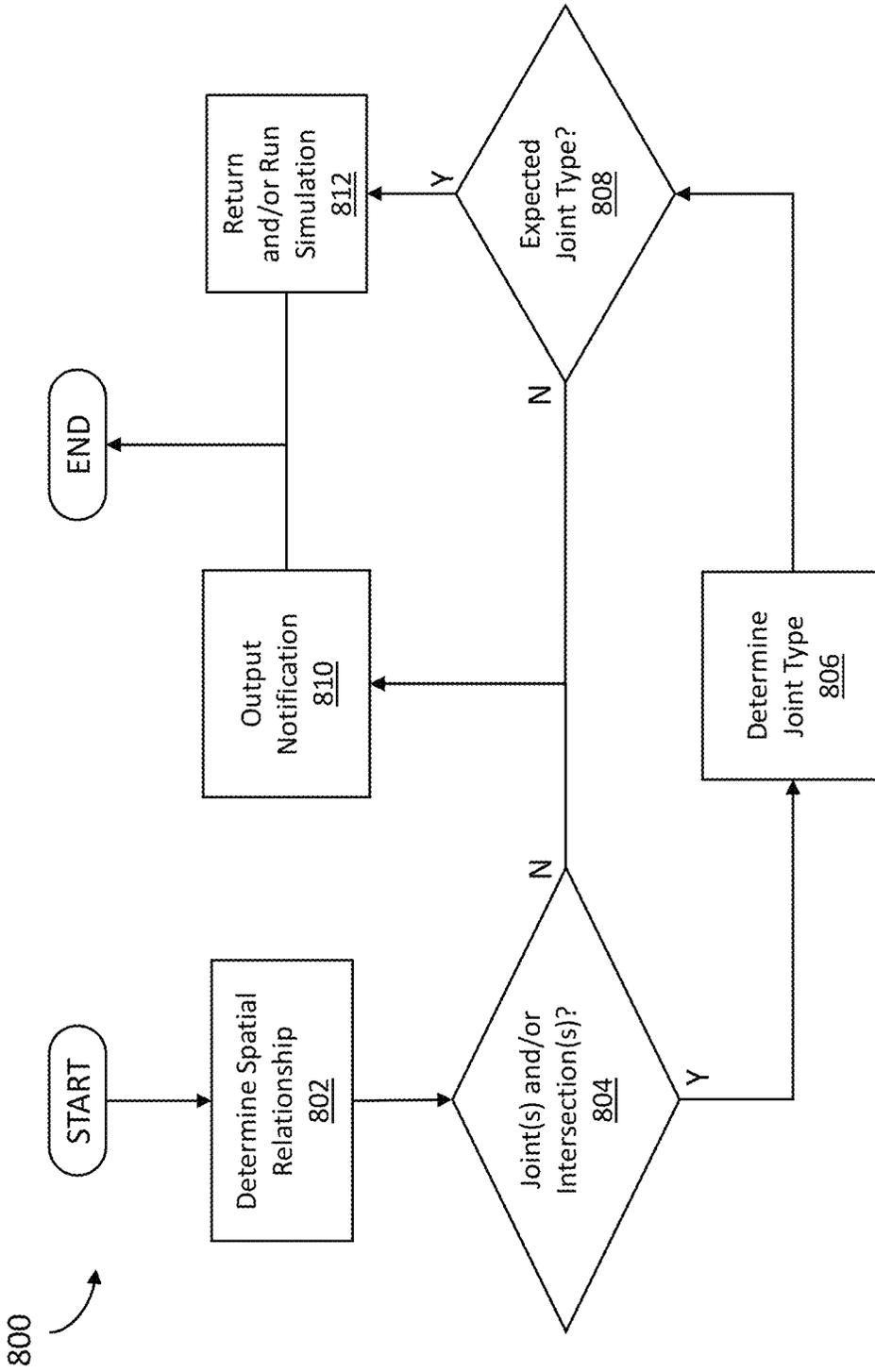


FIG. 8

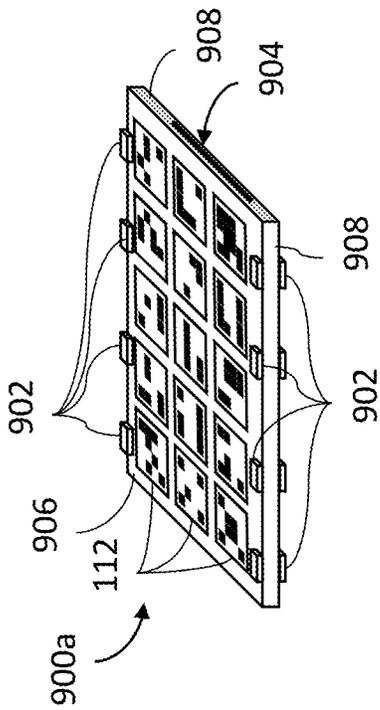


FIG. 9a

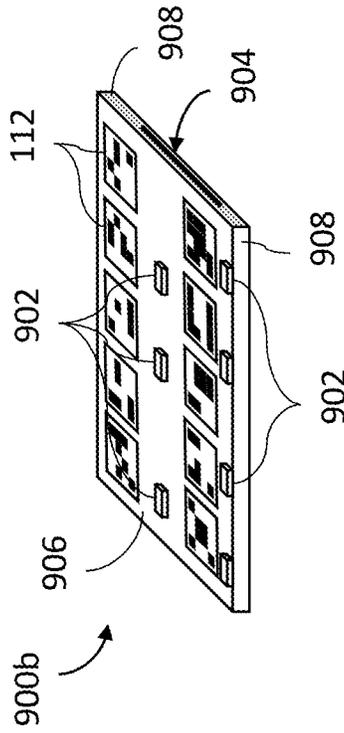


FIG. 9b

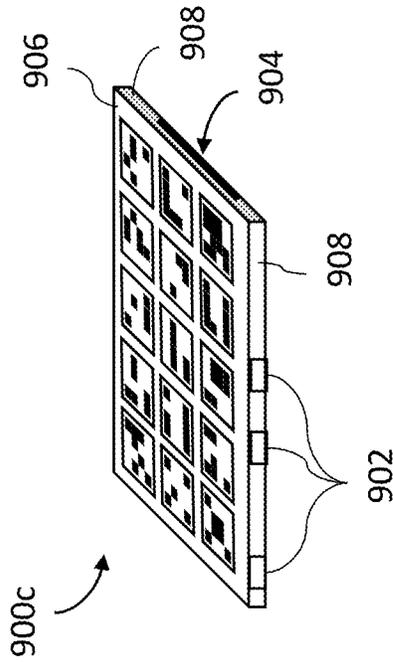


FIG. 9c

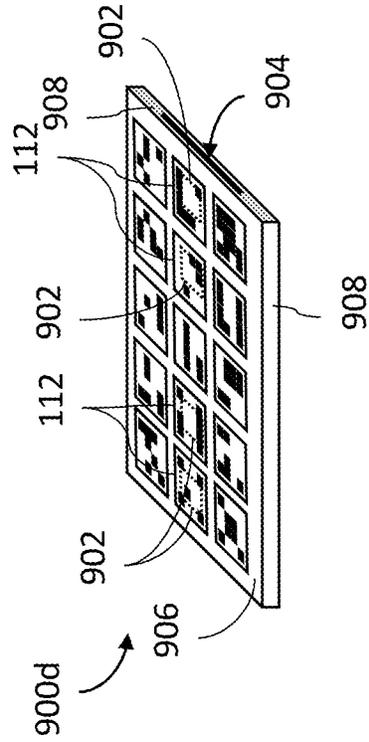


FIG. 9d

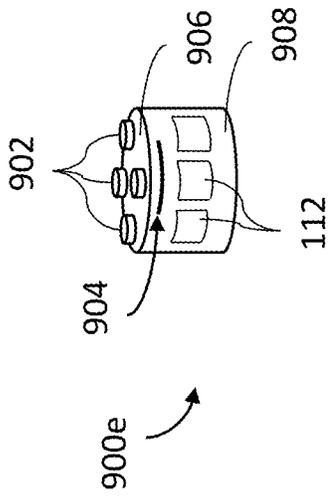


FIG. 9e

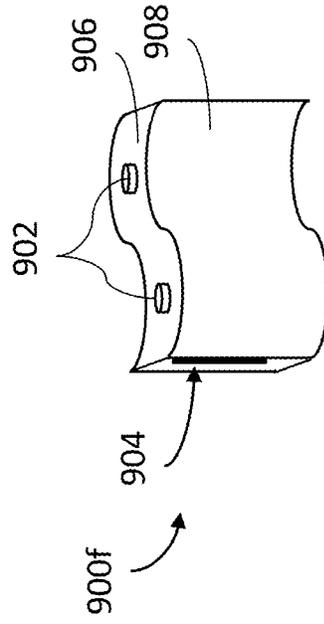


FIG. 9f

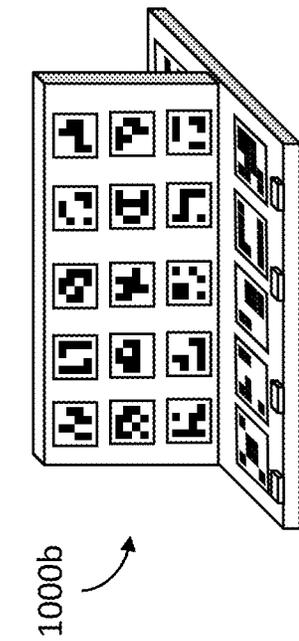


FIG. 10a

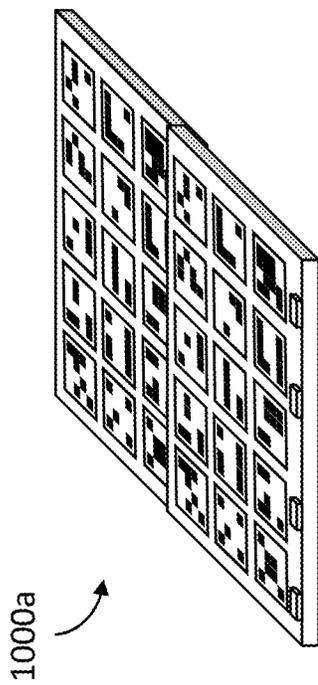


FIG. 10b

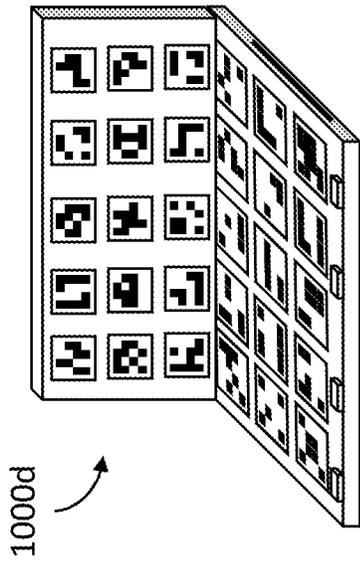


FIG. 10c



FIG. 10d

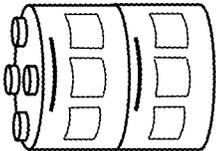


FIG. 10e

1000e

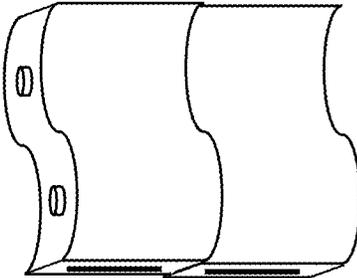


FIG. 10f

1000f

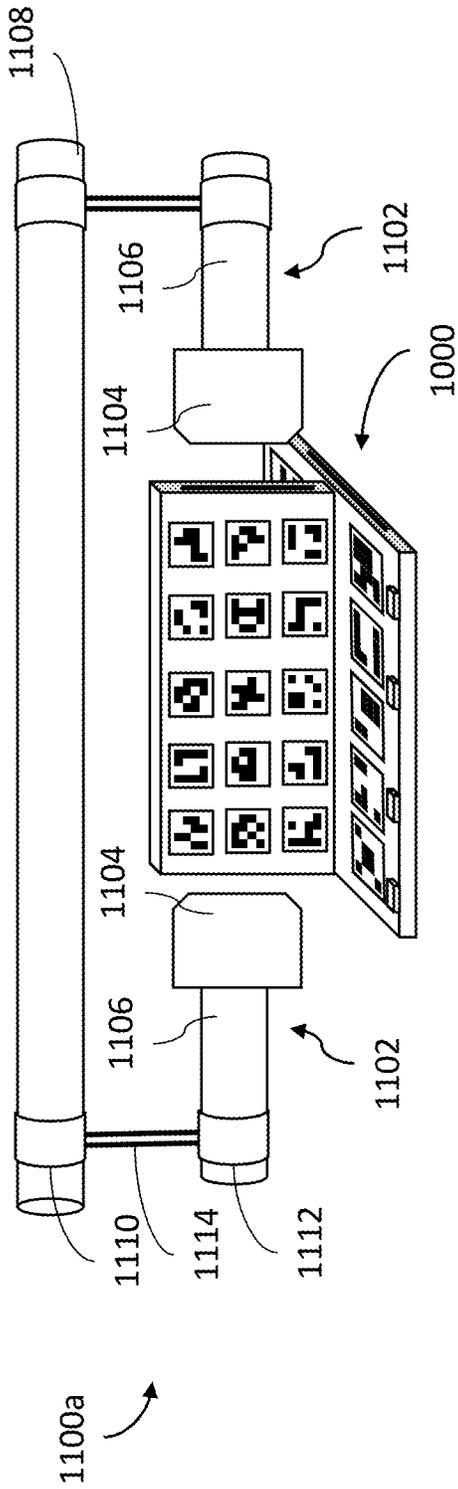


FIG. 11a

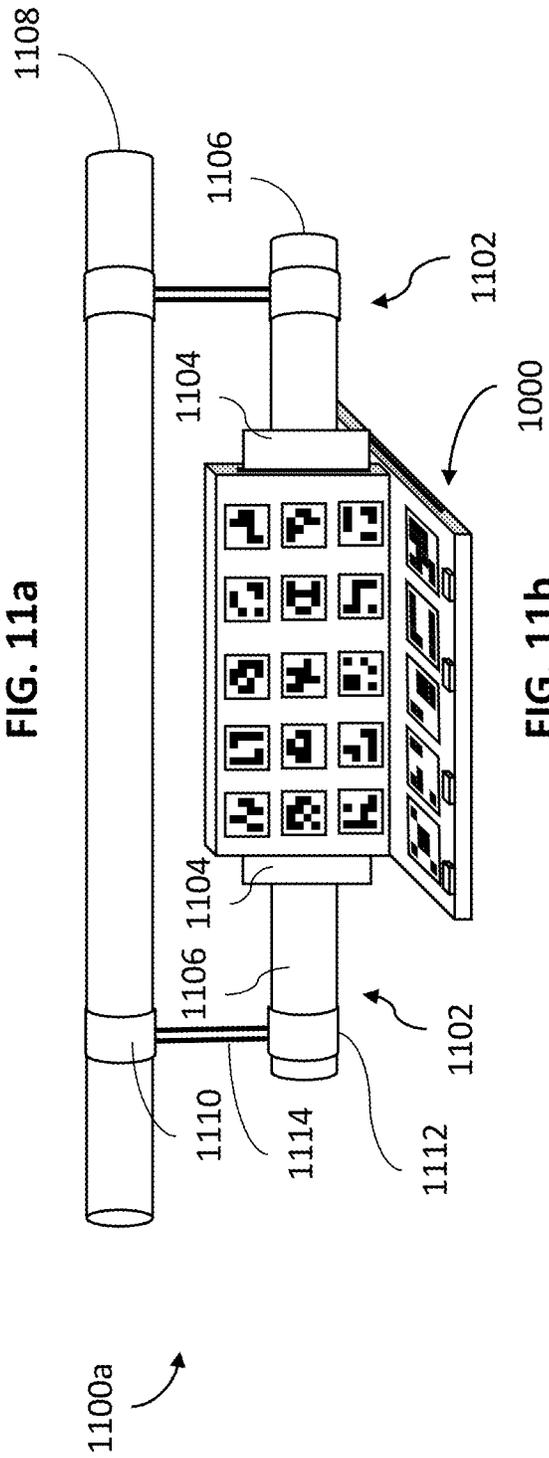


FIG. 11b

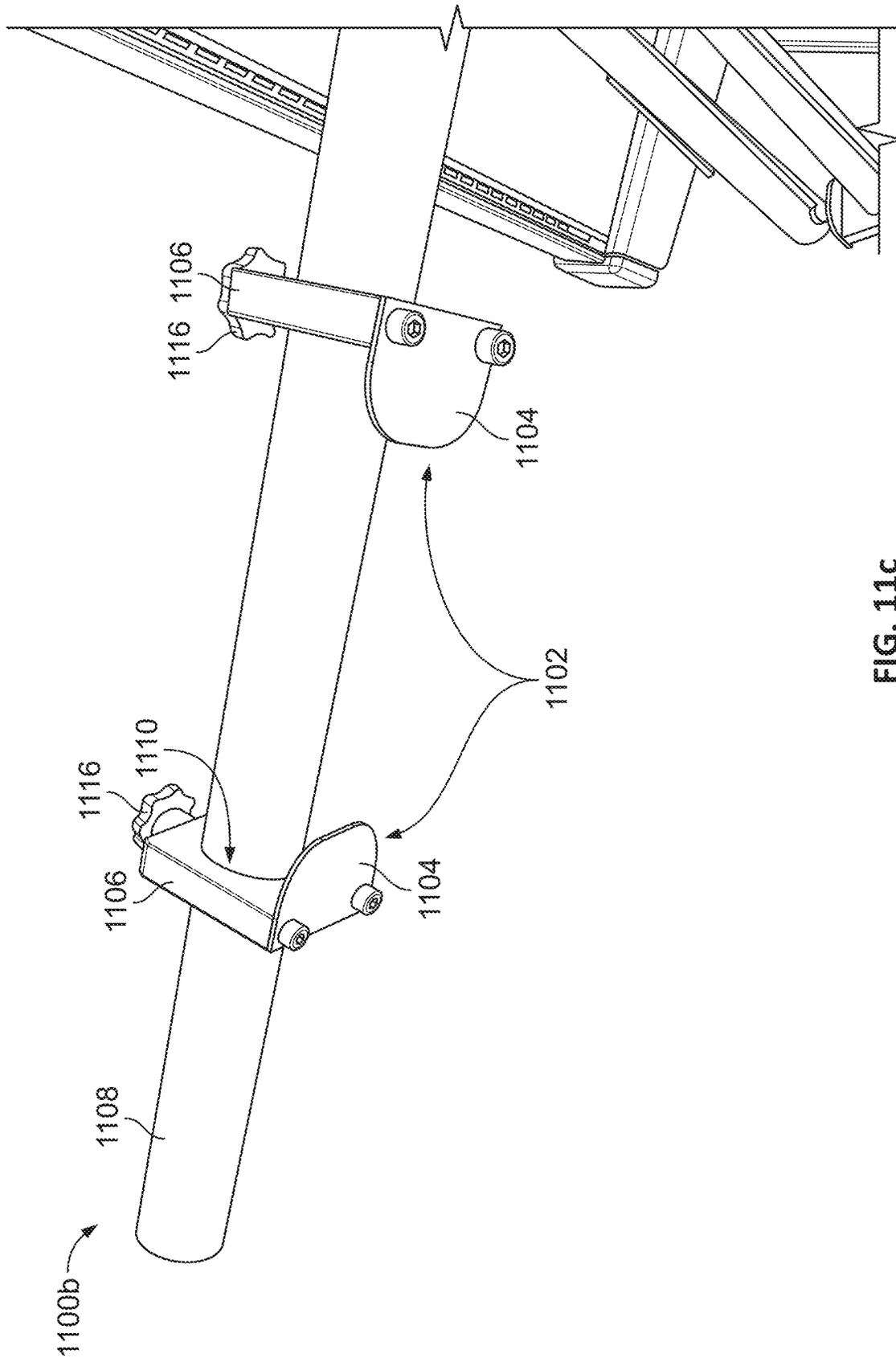


FIG. 11C

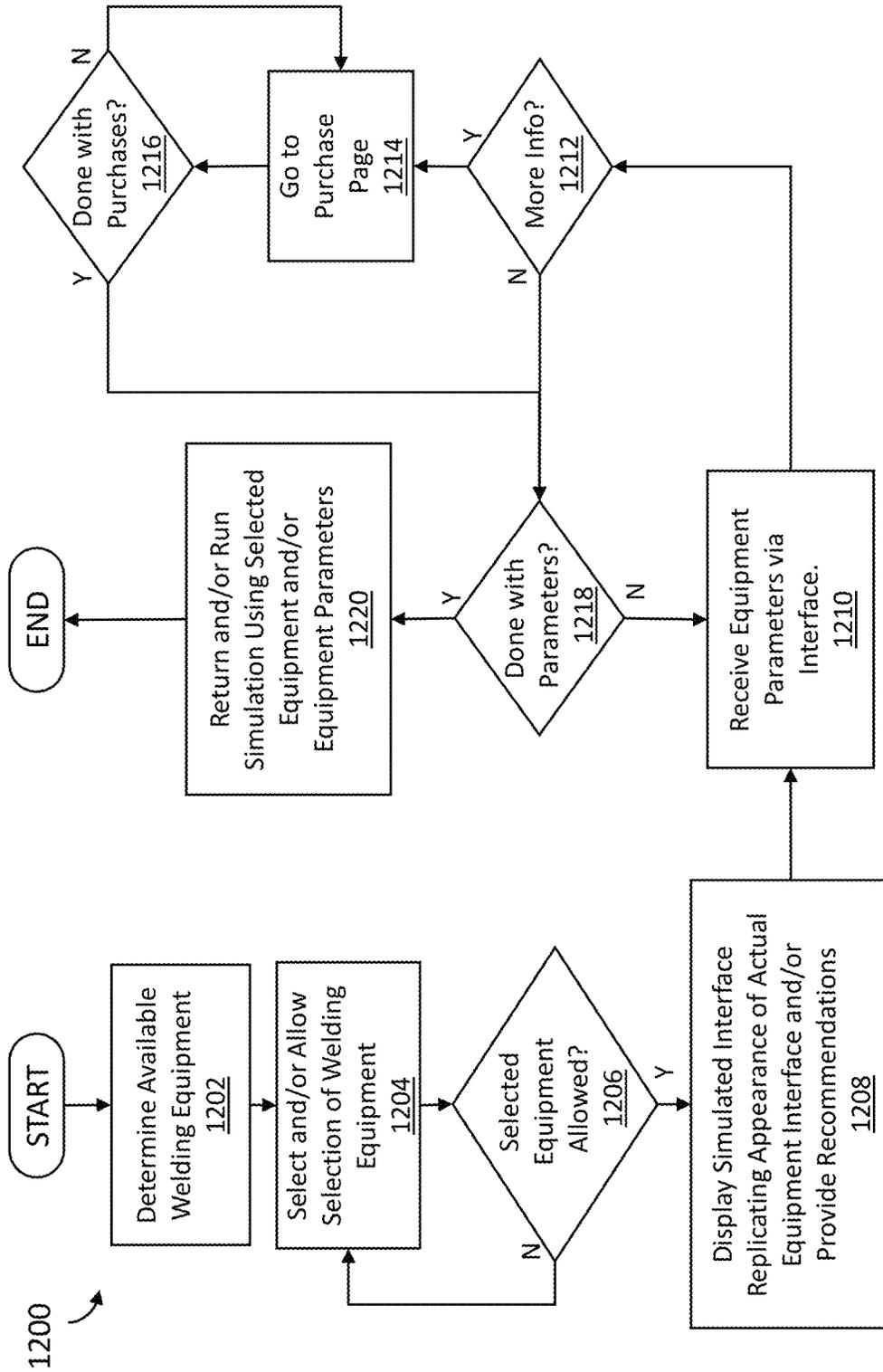


FIG. 12

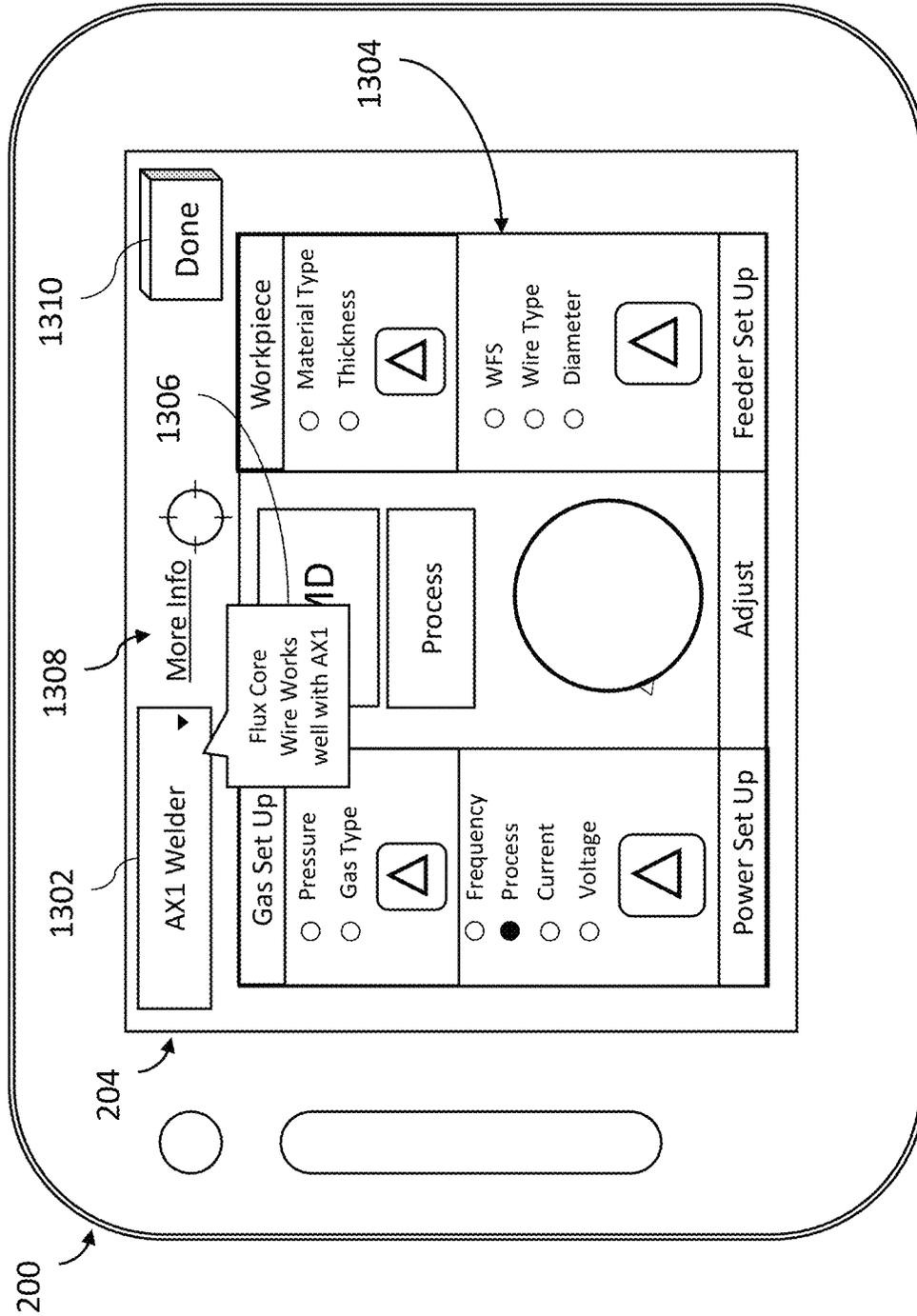


FIG. 13

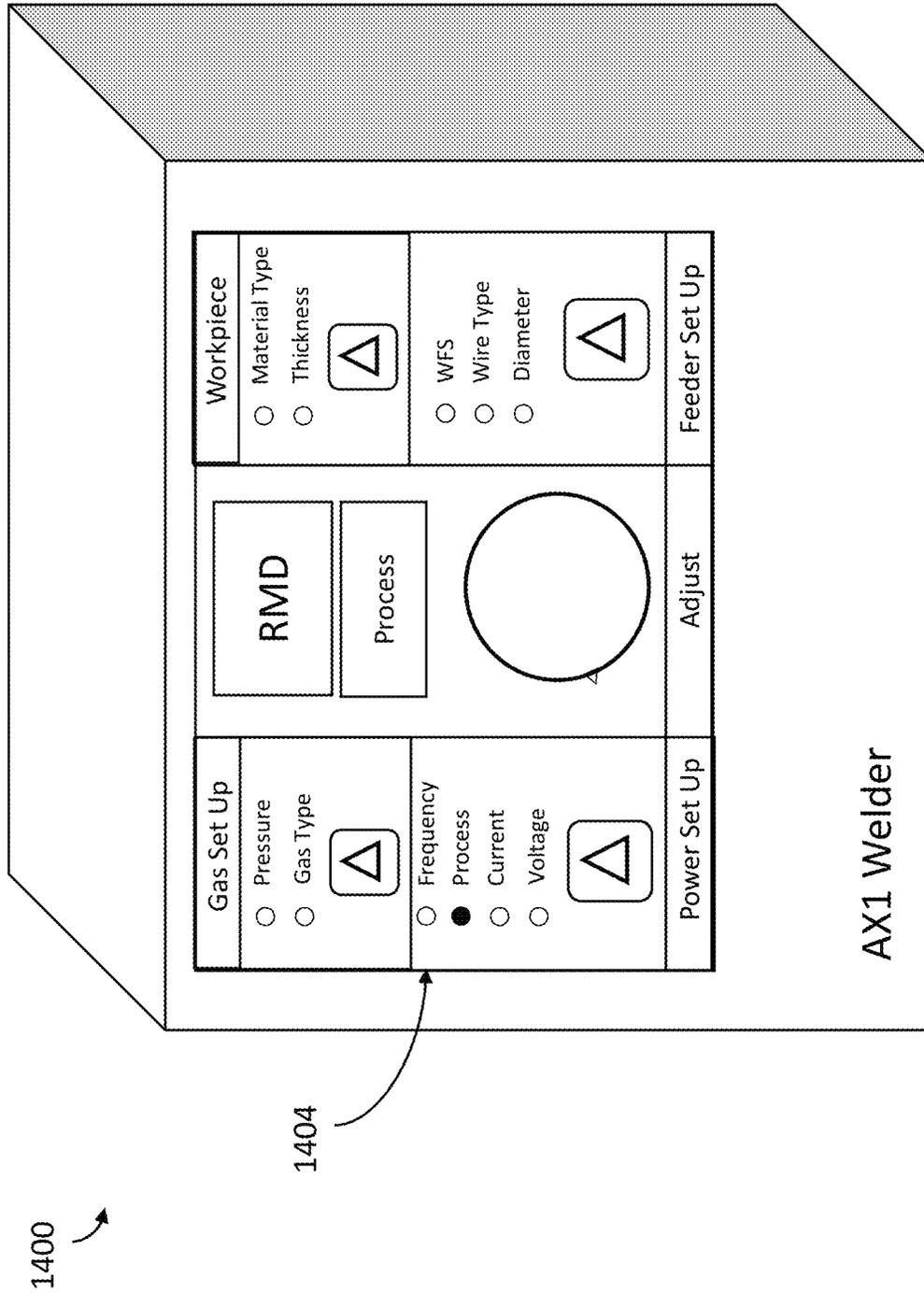


FIG. 14

**WELD TRAINING SIMULATIONS USING
MOBILE DEVICES, MODULAR
WORKPIECES, AND SIMULATED WELDING
EQUIPMENT**

CROSS REFERENCE TO RELATED
APPLICATIONS

The present application claims the benefit of, and priority to, Provisional Patent Application No. 62/940,138, entitled "WELD TRAINING SIMULATIONS USING MOBILE DEVICES, MODULAR WORKPIECES, AND SIMULATED WELDING EQUIPMENT," filed Nov. 25, 2019, the entire contents of which are hereby incorporated by reference.

TECHNICAL FIELD

The present disclosure generally relates to weld training simulations and, more particularly, to weld training simulations using mobile devices, modular workpieces, and simulated welding equipment.

BACKGROUND

The welding industry has a shortage of experienced and skilled operators. Additionally, it is difficult and expensive to train new operators using live welding equipment. Further, even experienced welders often have difficulty maintaining important welding techniques throughout welding processes. Thus, there is a demand for affordable training tools and equipment that help operators develop, maintain, and/or refine welding skills.

Simulated welding tools make it possible for both experienced and inexperienced weld operators to practice producing high quality welds prior to actually using the real welding equipment. Additionally, welding operators can test out different welding tools in a simulated environment prior to actually purchasing that particular welding tool. However, conventional systems and methods for simulating joining operations require substantial investments in equipment (e.g., processors, displays, practice workpieces, welding tool(s), sensor(s), etc).

Limitations and disadvantages of conventional and traditional approaches will become apparent to one of skill in the art, through comparison of such systems with the present disclosure as set forth in the remainder of the present application with reference to the drawings.

BRIEF SUMMARY

The present disclosure is directed to weld training simulations using mobile devices, modular workpieces, and simulated welding equipment, substantially as illustrated by and/or described in connection with at least one of the figures, and as set forth in the claims.

These and other advantages, aspects and novel features of the present disclosure, as well as details of an illustrated example thereof, will be more fully understood from the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1a depicts an example weld training system, in accordance with aspects of this disclosure.

FIG. 1b depicts another example weld training system, in accordance with aspects of this disclosure.

FIG. 2 is a block diagram showing example components of a mobile device of the weld training system of FIG. 1a, in accordance with aspects of this disclosure.

FIG. 3 is a flowchart illustrating an example welding simulation program of the example weld training systems of FIGS. 1a-1b, in accordance with aspects of this disclosure.

FIG. 4a depicts an example mobile device display during a normal operation of the example welding simulation program of FIG. 3, in accordance with aspects of this disclosure.

FIG. 4b depicts an example mobile device display during a tool-less operation of the example welding simulation program of FIG. 3, in accordance with aspects of this disclosure.

FIG. 4c depicts an example mobile device mounted to an example welding tool during a helmet-less operation of the example welding simulation program of FIG. 3, in accordance with aspects of this disclosure.

FIGS. 4d-4f depict an example mobile device display showing an options panel and example previews of the impact of certain selected options during the example welding simulation program of FIG. 3, in accordance with aspects of this disclosure.

FIG. 5 is a flowchart illustrating an example temperature detection process, in accordance with aspects of this disclosure.

FIG. 6 is a flowchart illustrating an example orientation configuration process, in accordance with aspects of this disclosure.

FIGS. 7a-7b illustrate different perspectives of an example welding tool, as may be captured by a camera sensor of the mobile device of FIG. 2 when the mobile device is mounted in different orientations, in accordance with aspects of this disclosure.

FIG. 8 is a flowchart illustrating an example workpiece configuration process, in accordance with aspects of this disclosure.

FIGS. 9a-9f depict example modular workpieces that may be used with the example weld training systems of FIGS. 1a-1b, in accordance with aspects of this disclosure.

FIGS. 10a-10f depict example workpiece assemblies constructed from some of the modular workpieces of FIGS. 9a-9f, in accordance with aspect of this disclosure.

FIGS. 11a-11b depicts an example fixturing system of the example weld training systems of FIGS. 1a-1b, in accordance with aspects of this disclosure.

FIG. 11c depicts an example of an alternative fixture system that may be used with the example weld training systems of FIGS. 1a-1b, in accordance with aspects of this disclosure.

FIG. 12 is a flowchart illustrating an example equipment configuration process, in accordance with aspects of this disclosure.

FIG. 13 depicts an example simulated equipment interface that may be displayed during operation of the example equipment configuration process of FIG. 12, in accordance with aspects of this disclosure.

FIG. 14 depicts example piece of welding equipment with an actual equipment interface that may be used as a basis for the simulated equipment interface of FIG. 13, in accordance with aspects of this disclosure.

The figures are not necessarily to scale. Where appropriate, the same or similar reference numerals are used in the figures to refer to similar or identical elements. For example, reference numerals utilizing lettering (e.g., workpiece 900a,

workpiece 900b) refer to instances of the same reference numeral that does not have the lettering (e.g., workpieces 900).

DETAILED DESCRIPTION

Some examples of the present disclosure relate to simulating (e.g., via augmented, mixed, and/or virtual reality) joining operations (e.g., welding, brazing, adhesive bonding, and/or other joining operations). While the following disclosure sometimes refers to welding and/or weld training as a shorthand, the disclosure is equally applicable to other joining operations.

Some example of the present disclosure relate to using mobile devices (e.g., smartphone, tablet, personal digital assistant, electronic book reader, ipod, etc.) for conducting welding simulations, such as for purposes of training. In some examples, it may be advantageous to use mobile devices due to their availability, relative affordability, and/or technical power. The disclosure further contemplates automatically detecting whether an orientation of the mobile device is proper for the simulation, and notifying the user if not.

The present disclosure additionally contemplates using modular workpieces for conducting welding simulations. In some examples, the modular workpieces may be configured to tool-lessly connect to, and/or disconnect from, other modular workpieces to form various workpiece assemblies. In some examples, tool-less connectors may be advantageous because they can be easily connected to and/or engaged with other connectors without the need for auxiliary tools (e.g., screwdrivers, hammers, etc.). Tool-less connectors may also be advantageous over adhesives, as the tool-less connectors may be continually connected, disconnected, and reconnected with negligible change to their effectiveness, unlike adhesives. In some examples, the welding simulation may further be configured to recognize different joints formed by the modular workpieces, and conduct the welding simulation accordingly.

The present disclosure further contemplates using simulated equipment interfaces that replicate the appearance of actual equipment interfaces of actual welding-type equipment. In some examples, this replication may help orient a user who is already familiar with a particular piece of welding-type equipment and/or its actual equipment interface, thereby making them more comfortable with the welding simulation. In some examples, the replication may help users who are unfamiliar with a particular piece of welding-type equipment become familiar with the welding-type equipment (and/or its interface). Additionally, the present disclosure contemplates simulating certain welding effects in accordance with the way the effects might occur in the real world when real welding is performed using the real world welding-type equipment.

Some examples of the present disclosure relate to a weld training system, comprising: a mobile electronic device configured to conduct a weld training simulation, the mobile electronic device comprising: a display screen, processing circuitry, and memory circuitry comprising computer readable instructions which, when executed by the processing circuitry, cause the processing circuitry to: select welding-type equipment, display, on the display screen, a simulated welding-type equipment interface based on the welding-type equipment that was selected, receive one or more simulation parameters selected via the simulated equipment interface, and conduct the weld training simulation using the one or more simulation parameters.

In some examples, the simulated welding-type equipment interface replicates an appearance of an actual equipment interface of the welding-type equipment. In some examples, the one or more simulation parameters comprise one or more of a welding current, a welding voltage, a pulse frequency, a gas type, a gas pressure, a wire type, wire diameter, a wire feed speed, a workpiece material type, or a workpiece material thickness. In some examples, the welding-type equipment comprises a welding-type power supply, a gas supply, a wire feeder, or a welding tool.

In some examples, the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to provide a recommendation of a welding consumable or complementary welding-type equipment based on the welding-type equipment that was selected. In some examples, the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to display, on the display screen, an option to purchase the welding-type equipment, welding consumable, or complementary welding-type equipment. In some examples, the option to purchase comprises a link to a purchase page where the welding-type equipment, welding consumable, or complementary welding-type equipment can be purchased.

In some examples, the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to receive an input representative of a selection of the welding-type equipment. In some examples, the welding simulation is conducted based on the welding-type equipment that was selected. In some examples, the welding simulation simulates a welding arc, a weld puddle, a weld bead, a welding sound, or a welding fume based on the welding-type equipment that was selected.

Some examples of the present disclosure relate to a weld training system, comprising: a mobile electronic device configured to conduct a weld training simulation, the mobile electronic device comprising: a display screen, processing circuitry, and memory circuitry comprising computer readable instructions which, when executed by the processing circuitry, cause the processing circuitry to: display, on the display screen, a plurality of selectable settings, receive one or more selections of the plurality of selectable settings, and display, on the display screen, a rendering based on the one or more selections, the rendering comprising a preview of the weld training simulation if the weld training simulation were conducted with the one or more selections.

In some examples, the rendering comprises a static image, an animation, or a previously recorded weld training simulation. In some examples, the rendering is of a welding tool or one or more feedback guides. In some examples, the plurality of selectable settings comprise a plurality of selectable feedback guide settings, a plurality of selectable simulation exercise settings, or a plurality of selectable user characteristic settings.

In some examples, the plurality of feedback guide settings comprise two or more of a work angle guide setting, a travel angle guide setting, travel speed guide setting, or a contact tip to work distance guide setting. In some examples, the plurality of simulation exercise settings comprise a push weld setting and a drag weld setting. In some examples, the plurality of user characteristic settings comprise a left handed characteristic setting and a right handed characteristic setting.

In some examples, the plurality of selectable settings comprise a plurality of selectable simulation exercise set-

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tings and a plurality of selectable user characteristic settings, and the display of the plurality of selectable simulation exercise settings is dependent upon which user characteristic setting of the plurality of selectable user characteristic settings is selected. In some examples, the one or more selections comprise one or more first selections, and the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to: receive one or more second selections of the plurality of selectable options, the one or more second selections being at least partially different from the one or more first selections, and adjust the display of the rendering based on one or more differences between the one or more first selections and the one or more second selections. In some examples, the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to conduct the weld training simulation based on the one or more selections.

Some examples of the present disclosure relate to a weld training system, comprising: a desktop electronic device configured to conduct a weld training simulation, the desktop electronic device comprising: a display screen, processing circuitry, and memory circuitry comprising computer readable instructions which, when executed by the processing circuitry, cause the processing circuitry to: select welding-type equipment, display, on the display screen, a simulated welding-type equipment interface based on the welding-type equipment that was selected, receive one or more simulation parameters selected via the simulated equipment interface, and conduct the weld training simulation using the one or more simulation parameters.

In some examples, the simulated welding-type equipment interface replicates an appearance of an actual equipment interface of the welding-type equipment. In some examples, the one or more simulation parameters comprise one or more of a welding current, a welding voltage, a pulse frequency, a gas type, a gas pressure, a wire type, wire diameter, a wire feed speed, a workpiece material type, or a workpiece material thickness. In some examples, the welding-type equipment comprises a welding-type power supply, a gas supply, a wire feeder, or a welding tool.

In some examples, the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to provide a recommendation of a welding consumable or complementary welding-type equipment based on the welding-type equipment that was selected. In some examples, the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to display, on the display screen, an option to purchase the welding-type equipment, welding consumable, or complementary welding-type equipment. In some examples, the option to purchase comprises a link to a purchase page where the welding-type equipment, welding consumable, or complementary welding-type equipment can be purchased.

In some examples, the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to receive an input representative of a selection of the welding-type equipment. In some examples, the welding simulation is conducted based on the welding-type equipment that was selected. In some examples, the welding simulation simulates a welding arc, a weld puddle, a weld bead, a welding sound, or a welding fume based on the welding-type equipment that was selected.

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Some examples of the present disclosure relate to a weld training system, comprising: a desktop electronic device configured to conduct a weld training simulation, the desktop electronic device comprising: a display screen, processing circuitry, and memory circuitry comprising computer readable instructions which, when executed by the processing circuitry, cause the processing circuitry to: display, on the display screen, a plurality of selectable settings, receive one or more selections of the plurality of selectable settings, and display, on the display screen, a rendering based on the one or more selections, the rendering comprising a preview of the weld training simulation if the weld training simulation were conducted with the one or more selections.

In some examples, the rendering comprises a static image, an animation, or a previously recorded weld training simulation. In some examples, the rendering is of a welding tool or one or more feedback guides. In some examples, the plurality of selectable settings comprise a plurality of selectable feedback guide settings, a plurality of selectable simulation exercise settings, or a plurality of selectable user characteristic settings.

In some examples, the plurality of feedback guide settings comprise two or more of a work angle guide setting, a travel angle guide setting, travel speed guide setting, or a contact tip to work distance guide setting. In some examples, the plurality of simulation exercise settings comprise a push weld setting and a drag weld setting. In some examples, the plurality of user characteristic settings comprise a left handed characteristic setting and a right handed characteristic setting.

In some examples, the plurality of selectable settings comprise a plurality of selectable simulation exercise settings and a plurality of selectable user characteristic settings, and the display of the plurality of selectable simulation exercise settings is dependent upon which user characteristic setting of the plurality of selectable user characteristic settings is selected. In some examples, the one or more selections comprise one or more first selections, and the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to: receive one or more second selections of the plurality of selectable options, the one or more second selections being at least partially different from the one or more first selections, and adjust the display of the rendering based on one or more differences between the one or more first selections and the one or more second selections. In some examples, the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to conduct the weld training simulation based on the one or more selections.

FIG. 1a shows an example weld training system 100. The weld training system 100 includes a mobile device 200 retained by a device mount 102 secured to a welding helmet shell 104. In some examples, the device mount 102 may be considered part of the mobile device 200. As shown, the device mount 102 includes two mounted sensors 106. In some examples, the device mount 102 may include more or less mounted sensors 106. In some examples, the mounted sensors 106 may include, for example, one or more temperature sensors, accelerometers, magnetometers, gyroscopes, proximity sensors, pressure sensors, light sensors, motion sensors, position sensors, ultrasonic sensors, infrared sensors, Bluetooth sensors, and/or near field communication (NFC) sensors.

In the example of FIG. 1a, the mobile device 200 includes one or more camera sensors 208. While only one camera

sensor **208** is shown in the example of FIG. **1a** for the sake of simplicity, in some examples, the mobile device **200** may include several camera sensors **208**. The mobile device **200** also includes mobile sensors **206**, as further discussed below with respect to FIG. **2**. In the example of FIG. **1a**, the one or more camera sensors **208** have a field of view (FOV) **108** that is unobstructed by the device mount **102** and welding helmet shell **104**. As shown, the device mount **102** includes multiple apertures **110**, such that the camera sensor(s) **208** may have an unobstructed FOV **108** in multiple different orientations. The mobile device **200** further includes several lights **202**. In some examples, one or more of the lights **202** may help illuminate the FOV **108**.

While the device mount **102** is shown as a clamshell case in the example of FIG. **1a** for ease of illustration, in some examples, the device mount **102** may instead comprise an elastic webbing with a multitude of apertures **110**. In some examples, the device mount **102** and/or helmet shell **104** may be configured such as shown in U.S. patent application Ser. No. 16/694,937, entitled "SYSTEMS FOR SIMULATING JOINING OPERATIONS USING MOBILE DEVICES," filed Nov. 25, 2019, the entirety of which is hereby incorporated by reference. Though not shown in FIG. **1a**, in some examples, the device mount **102** and welding helmet shell **104** may be configured such that the mobile device **200** may be retained with a display screen **204** of the mobile device **200** visible to a wearer of the welding helmet shell **104**. In some examples, the mobile device may instead be retained by goggles and/or some sort of head mounted wearable. In some examples, the device mount **102** may be secured to a different type of helmet shell **104** and/or headwear.

In some examples, the device mount **102** may be removably secured such that the device mount **102** may be toollessly separated from one helmet shell **104** and then toollessly secured to a different helmet shell **104**. In some examples, the device mount **102** may be configured for attachment to the helmet shell **104** in multiple different orientations (e.g., left and right landscape orientations). In such an example, the orientation of the mobile device **200** may be adjusted by adjusting the attachment orientation of the device mount **102** to the helmet shell **104**.

FIG. **1b** shows another example weld training system **100b**. The weld training system **100b** is similar to the weld training system **100a**, except that the weld training system **100b** includes a desktop device **250** instead of a mobile device **200**. In some examples, the desktop device **250** may be a desktop computer (and/or similar computing apparatus) housed in a welding power supply façade. As shown, the desktop device **250** is a separate apparatus that is connected to the helmet shell **104** via cable **252** rather than mounted to helmet shell **104** via device mount **102** like the mobile device **200**. While one cable **252** is shown in the example of FIG. **1b**, in some examples, the cable **252** may be a bundle of several different cables (e.g., to route power, communications signals, etc.) While not shown in the example of FIG. **1b**, in some examples, the desktop device **250** may be connected to mains power, such as through one or more power cables.

In the example of FIG. **1b**, the desktop device **250** includes a display screen **204** on a housing of the desktop device **250**, as well as a display screen **204** mounted to an interior of the helmet shell **104**, where it is viewable by an operator wearing the helmet shell **104**. Additionally, the mounted sensors **106** are mounted to the helmet shell **104** directly rather than through the device mount **102**. Further, the camera sensor(s) **208** and lights **202** are mounted to the

helmet shell **104**. In some examples, the desktop device **250** may power and/or communicate with the devices mounted to the helmet shell **104** through cable **252**. In some examples, the helmet shell **104** may be considered part of the desktop device **250**.

While the below disclosure focuses on the mobile device **200** of FIG. **1a**, in some examples, some or all of the disclosure pertaining to the mobile device **200** may pertain equally to the desktop device **250**. For example, content disclosed as being displayed on the display screen **204** of the mobile device **200** may, in some examples, instead (or additionally) be displayed on the display screen(s) **204** of the desktop device **250**. As another example, various components depicted and/or described as being part of the mobile device **200** (e.g., with respect to FIG. **2**) may, in some examples, instead (or additionally) be part of the desktop device **250**.

In the examples of FIGS. **1a-1b**, a welding tool **700** and a workpiece assembly **1000** are in the FOV **108** of the camera sensor(s) **208** of the mobile device **200**. As shown, the workpiece assembly **1000** comprises two workpieces **900** connected together, as further discussed below. Both workpieces **900** of the workpiece assembly **1000** include markers **112**. As shown, the workpiece assembly **1000** is retained by a fixturing system **1100**, as further discussed below.

In the examples of FIGS. **1a-1b**, the welding tool **700** is a welding torch or gun, such as a torch or gun configured for gas metal arc welding (GMAW). In some examples, the welding tool **700** may be an electrode holder (i.e., stinger) configured for shielded metal arc welding (SMAW). In some examples, the welding tool **700** may comprise a torch and/or filler rod configured for gas tungsten arc welding (GTAW). In some examples, the welding tool **700** may comprise a gun configured for flux-cored arc welding (FCAW).

In the examples of FIGS. **1a-1b**, the welding tool **700** includes markers **112** disposed on its nozzle **702**. As shown, the welding tool **700** also includes a handle **704** having a trigger **706**. A gooseneck **708** that leads to the nozzle **702** is attached to one end of the handle **704**, while a communication module **710** is attached to the opposite end of the handle **704**. In some examples, the communication module **710** may include communication circuitry configured for communication with communication circuitry **210** of the mobile device **200**. In some examples, the welding tool **700** and/or communication module **710** may include one or more audio, visual, and/or vibration devices. In some examples, the communication module **710** may be configured to send one or more signals to the mobile device **200** when the trigger **706** is activated.

In some examples, the welding tool **700** may include markers **112** on other portions of the welding tool **700** (e.g., handle **704**, gooseneck **708**, communication module **710**, and/or trigger **706**). While shown as pattern markers in the examples of FIGS. **1a-1b**, in some examples, the markers **112** (both on the welding tool **700** and/or workpiece(s) **900**) may instead be reflectors, light emitting markers (e.g., LEDs), ultrasonic emitters, electromagnetic emitters, and/or other types of active and/or passive markers. In some examples, the markers **112** may be permanently affixed to, imprinted on, embedded in, and/or removably connected to the welding tool **700** and/or workpiece(s) **900**. In some examples, each marker **112** may be uniquely recognizable when alone and/or when arranged with other markers **112** such that a particular combination and/or configuration of markers **112** are uniquely recognizable.

In some examples, the mobile device **200** may capture sensor data (e.g., images) relating to the welding tool **700** and/or workpiece(s) **900**. In some examples, the mobile device **200** may determine a position, orientation, motion, configuration, and/or other characteristic(s) of the welding tool **700** and/or workpiece(s) **900** based on an analysis of the sensor data. In some examples, the markers **112** may assist in this analysis. For example, one or more characteristics of the markers **112** may be recognized and/or interpreted to help determine the position, orientation, motion, configuration, and/or other characteristic of the welding tool **700** and/or workpiece(s) **900**. In some examples, the mobile device **200** may be configured to conduct a welding simulation using the sensor data, and/or positions, orientations, motions, configurations, and/or other characteristics of the welding tool **700** and/or workpiece(s) **900**. In some examples, image recognition techniques may be utilized in recognizing and/or interpreting the markers **112**, welding tool **700**, and/or workpiece(s) **900**. In some examples, the welding tool **700** and/or workpiece(s) **900** may be markerless, and the weld training system **100** may use markerless techniques to determine position, orientation, configuration, and/or other characteristics of the welding tool **700** and/or workpiece(s) **900**.

In the examples of FIGS. **1a-1b**, the weld training system **100** further includes one or more remote servers **114** and one or more remote displays **116**. As shown, the mobile device **200** is in communication with the one or more remote servers **114** and one or more remote displays **116**, such as through communication circuitry **210** of the mobile device **200**, for example. In some examples, the mobile device **200** may be in communication with the one or more remote servers **114** and one or more remote displays **116** through a network (e.g., a local area network, wide area network, the internet, etc.). In some examples, the mobile device **200** may be configured to upload and/or download data (e.g., simulation and/or training data) to/from the remote display(s) **116** and/or remote server(s) **114**. In some examples, the remote display(s) **116** may be configured to display a mirror image (and/or similar image) of the display screen **204** of the mobile device **200**. While shown as separate in the examples of FIGS. **1a-1b**, in some examples, one or more of the remote servers **114** and/or remote displays **116** may be in proximity to, interconnected with, and/or in communication with one another.

FIG. **2** is a block diagram showing example components of the mobile device **200**. As shown, the mobile device **200** includes several components in electrical communication with one another via a common electrical bus **201**. In particular, the mobile device **200** includes one or more data ports **212**, speakers **214**, lights **202**, other output devices **216** (e.g., vibration devices), input devices **218**, camera sensors **208**, and/or other mobile sensors **206**. The mobile device **200** further includes communication circuitry **210**, audio circuitry **220**, processing circuitry **222**, graphics circuitry **224**, memory circuitry **226**, and a display screen **204**.

In some examples, the components of the mobile device **200** may reside on one or more printed circuit boards (PCBs) and/or flex circuits. While not shown in the example of FIG. **2** for the sake of simplicity, in some examples the mobile device **200** may further include a power source in electrical communication with, and/or configured to supply power to, the various components of the mobile device **200**. In some examples, the display screen **204** may be a touch screen configured to detect and/or receive touch based input (e.g., via capacitive, acoustic, inductive, and/or resistive touch-screen sensors). In some examples, the input devices **218**

may include, for example, one or more touchscreen elements, microphones, physical buttons, gesture controls, biometric sensors, and/or other types of input devices that generate electric signals in response to user input.

In some examples, the camera sensor(s) **208** may include one or more adjustable lenses, filters, and/or other optical components for capturing electromagnetic waves in one or more spectra, such as, for example, infrared, visible, and/or ultraviolet. In some examples, two or more of the camera sensors **208** may implement stereoscopic tracking and/or capture stereoscopic images. In some examples, one or more of the camera sensors **208** and one or more of the mounted sensors **106** may implement stereoscopic tracking and/or capture stereoscopic images. In some examples, one or more of the other mobile sensors **206** may comprise temperature sensors, accelerometers, magnetometers, gyroscopes, proximity sensors, pressure sensors, light sensors, motion sensors, position sensors, ultrasonic sensors, infrared sensors, Bluetooth sensors, and/or near field communication (NFC) sensors.

In some examples, the communication circuitry **210** may be configured for wireless communication with the communication module **710** of the welding tool **700**, remote server(s) **114**, and/or remote display(s) **116** via one or more wireless communication protocols. For example, the one or more wireless communication protocols may include NFC protocols, cellular protocols (e.g., GSM, IS-95, UMTS, CDMA, LTE, etc.), IEEE 802.15.4 based protocols in the 2.4 GHz industrial, scientific, and medical (ISM) radio band (commonly known as Zigbee), low frequency magnetic signal protocols being transmitted at a frequency of approximately 131-134 kHz in conformance with IEEE 1902.1 standard (commonly known as Rubee), short wavelength ultra high frequency radio communication protocols in the 2.400 to 2.485 GHz ISM band in conformance with IEEE 802.15.1 standard (commonly known as Bluetooth), communication protocols in conformance with the IEEE 802.11 standard (commonly known as Wifi), and/or other appropriate communication protocols. Though not shown in the example of FIG. **2**, in some examples, the communication circuitry **210** may be in electrical communication with an antenna of the mobile device **200**.

In some examples, the audio circuitry **220** may include circuitry configured to drive the one or more speakers **214**. In some examples, the graphics circuitry **224** may include one or more graphical processing units (GPUs), graphical driver circuitry, and/or circuitry configured to drive graphical display on the display screen **204**. In some examples, the graphics circuitry **224** may be configured to generate one or more simulation (e.g., augmented reality, mixed reality, and/or virtual reality) images on the display screen **204** during a welding simulation.

In some examples, the processing circuitry **222** may include one or more processors. In the example of FIG. **2**, the memory circuitry **226** includes (and/or stores) a welding simulation program **300**. As shown, the welding simulation program **300** includes a temperature detection process **500**, an orientation configuration process **600**, a workpiece configuration process **800**, and an equipment configuration process **1200**. In some examples, the temperature detection process **500**, orientation configuration process **600**, workpiece configuration process **800**, and/or equipment configuration process **1200** may be separate from the welding simulation program **300**. In some examples, the welding simulation program **300** may comprise machine readable instructions configured to be executed by the processing circuitry **222**.

FIG. 3 is a flowchart illustrating an example operation of the welding simulation program 300. In the example of FIG. 3, the welding simulation program 300 begins at block 302. At block 302, certain simulation parameters of the simulation program 300 are configured and/or selected during a preliminary configuration. The simulation parameters may include, for example, one or more simulation exercises, joint types, tutorial settings, goals, difficulty settings, feedback settings, realism settings, sensor settings, lighting settings, input device settings, output device settings, communication settings, simulation modes, fixture parameters, equipment types, equipment parameters, thresholds, product credentials, user credentials, user characteristics, upload settings, screen mirroring settings, marking parameters, and/or other appropriate settings and/or parameters. In some examples, the simulation program 300 may conduct a welding simulation based, at least in part, on some or all of these simulation parameters.

In some examples, a simulation exercise may comprise a predefined activity, test, and/or task for a user to complete during a welding simulation. In some examples, a simulation exercise may be automatically determined and/or selected by the simulation program 300, such as, for example, based on a selected/determined joint type and/or other simulation parameter. In some examples, a simulation exercise may be a freeform exercise, where there is no predefined task, and a user is instead given free reign to weld in whatever manner they wish.

In some examples, a joint type may comprise a type of joint defined by an intersection of two workpieces 900 in a workpiece assembly 1000. In some examples, a joint type may comprise, for example, a lap joint, a butt joint, a corner joint, a T joint, an edge joint, and/or a pipe joint. In some examples, a joint type may be automatically determined and/or selected by the simulation program 300, such as, for example, based on sensor data, a selected simulation exercise, and/or some other simulation parameter.

In some examples, a tutorial may be an audio, pictorial, and/or video tutorial that is output to a user through appropriate mechanisms of the mobile device 200. In some examples, a selected tutorial may be output prior to and/or during a welding simulation. In some examples, a tutorial may be interactive, requiring some input from user to complete. In some examples, a tutorial may be automatically determined and/or selected by the simulation program 300, such as, for example, based on a selected/determined exercise, joint type, goal, difficulty, feedback, realism, and/or other simulation parameters.

In some examples, a goal may be an objective and/or target grade and/or score for a user to achieve during a welding simulation. In some examples, the goal may be automatically determined and/or selected by the simulation program 300, such as, for example, based on a selected/determined exercise, joint type, difficulty, realism, mode, and/or other simulation parameter(s). In some examples, a difficulty (e.g., very easy, easy, normal, hard, very hard, etc.) may refer to how ambitious a goal may be, and/or how strict and/or stringent may be the scoring of the welding simulation. In some examples, the difficulty may be automatically determined and/or selected by the simulation program 300, such as, for example, based on a selected/determined exercise, realism, mode, and/or other simulation parameter(s).

In some examples, a feedback setting may indicate the means by which feedback should be provided to a user during the welding simulation. For example, feedback may be provided through audio, visual, vibration, and/or other means. In some examples, a feedback setting may indicate

how much and/or how little feedback should be provided to the user during the welding simulation. For example, feedback may be provided with respect to all or some equipment parameters and/or welding technique parameters (e.g., tool angle, tool aim, tool speed, tool position, contact tip to work distance, workpiece position, workpiece orientation, workpiece configuration, equipment parameters, etc.). In some examples, a feedback setting may allow suppression of feedback with respect to some or all equipment parameters and/or welding technique parameters. In some examples, a feedback setting may allow suppression of feedback with respect to all but one equipment parameter and/or welding technique parameter. In some examples, a feedback setting may be automatically determined and/or selected by the simulation program 300, such as, for example, based on a selected/determined simulation exercise, joint type, tutorial, goal, difficulty, realism, and/or other appropriate simulation settings and/or parameters.

In some examples, a realism setting (e.g., low, medium, high, etc.) may indicate how close to reality the welding simulation attempts to adhere. For example, the welding simulation may simulate or omit certain things that sometimes occur during real life welding (e.g., sounds, smoke, fumes, lights, vibrations, resistance, anomalies, impurities, burn through, etc.) based on a realism setting. In some examples, the realism setting may impact certain performance quality settings (e.g., of the display screen 204, graphics circuitry 224, etc.). In some examples, a realism setting may be automatically determined and/or selected by the simulation program 300, such as, for example, based on a selected/determined simulation exercise, goal, difficulty, and/or other appropriate simulation settings and/or parameters.

In some examples, sensor settings may be settings pertaining to the camera sensor(s) 208 and/or mobile sensors 206 of the mobile device 200, and/or the mounted sensors 106 of the device mount 102. In some examples, sensor settings may include autofocus and/or auto-tracking settings of the camera sensor(s) 208. In some examples, sensor settings may include a calibration of one or more of the camera sensors 208 and/or mobile sensors 206 (e.g., accelerometers and/or gyroscopes). In some examples, lighting settings may include settings pertaining to the lights 202 of the mobile device, such as, for example, brightness, intensity, when to be on/off, how long to stay on/off, and/or other appropriate settings. In some examples, certain lighting settings may be automatically determined and/or selected by the simulation program 300, such as, for example, based on a selected/determined simulation exercise, goal, difficulty, realism, and/or other appropriate settings and/or parameters.

In some examples, input and/or output device settings may be settings pertaining to the input and/or output devices of the mobile device 200 (e.g., input devices 218, display screen 204, speaker(s) 214, etc.). For example, an input device setting may turn on/off a microphone and/or touch screen sensitivity of the display screen 204. As another example, an output device setting may be a volume of the speaker 214 and/or a brightness, color, resolution, and/or graphics quality of the display screen 204. In some examples, certain input and/or output device settings may be automatically determined and/or selected by the simulation program 300, such as, for example, based on a selected/determined exercise, tutorial, mode, feedback, realism, and/or other appropriate settings and/or parameters.

In some examples, communication settings may be settings pertaining to the communication circuitry 210 of the mobile device 200. For example, the communication set-

tings may control and/or impact the connection between the mobile device **200** and the communication module **710** of the welding tool **700**, the remote server(s) **114**, and/or the remote display(s) **116**. For example, the communication settings may control and/or impact the communication protocols used by the mobile device **200** to communicate with the communication module **710** of the welding tool **700**, the remote server(s) **114**, and/or the remote display(s) **116**. In some examples, the communication settings may include a unique identifier of the communication module **710** and/or welding tool **700**, to enable communication between the mobile device **200** and welding tool **700**.

In some examples, simulation modes may set different modes of operation for the welding simulation. For example, selecting a normal mode of operation may lead to a normal simulation that overlays simulation images onto the welding tool **700**, workpiece assemblies **1000**, and/or other objects in the FOV **108** of the user (e.g., via the mobile device **200**) when wearing the welding helmet shell **104**. FIG. **4a** shows an example of a display screen **204** of a mobile device **200** during a normal mode of operation.

In some examples, selecting a tool-less mode of operation may lead to a more simplified welding simulation that does not use the welding tool **700** and/or workpieces **900**. Instead of using a welding tool **700**, in some examples, a user may use their finger(s) and/or stylus to deliver touch screen inputs and/or perform the welding simulation during a tool-less mode of operation. FIG. **4b** shows an example of a display screen **204** of a mobile device **200** during a tool-less mode of operation.

In some examples, selecting a helmet-less mode of operation may configure the welding simulation program **300** for operation without a helmet shell **104**. In such an example, the mobile device **200** may be secured to the welding tool **700** instead of the helmet shell **104**, such as via the device mount **102** and/or a torch mount **450**. FIG. **4c** shows an example of the mobile device **200** mounted to the welding tool **700** during a helmet-less mode of operation. In some examples, a simulation mode may be automatically determined and/or selected by the simulation program **300**, such as, for example, based on a selected/determined exercise, realism, communication settings, and/or other appropriate simulated settings and/or parameters.

In some examples, a fixture parameter may be a location, configuration, and/or orientation of the fixturing system **1100**. In some examples, one or more fixture parameters may be automatically determined and/or selected by the simulation program **300** via a calibration process. In some examples, an equipment type may include a type and/or model of a welding tool **700**, a welding power supply, a wire feeder, a gas supply, and/or a gas valve. In some examples, an equipment parameter may be a parameter of a piece of welding-type equipment (e.g., power supply, gas supply valve, wire feeder, welding tool **700**, etc.). Examples of equipment parameters include a welding process, current, voltage, pulse frequency, wire type, wire diameter, wire feed speed, pressure, workpiece material type, and/or workpiece material thickness. In some examples, a threshold may be an upper or lower limit on some parameter, such as, for example, a temperature and/or remaining power of the mobile device **200**.

In some examples, a product credential may be a unique identifier (e.g., serial number) of the weld training system **100** and/or a component of the weld training system **100** (e.g., mobile device **200**, simulation program **300**, helmet shell **103**, torch **700**, etc.). In some examples, a user credential may be a username, unique identifier, and/or pass-

word of a user. In some examples, product credentials and/or user credentials may be sent to and/or verified by the remote server(s) **114**.

In some examples, user characteristics may include, for example, one or more preferred simulation parameters, dominant hand, height, experience, qualifications, completed exercises, assigned exercises, scores, and/or other characteristics of a user. In some examples, user characteristics may be received by the mobile device **200** from the remote server(s) **114**, such as in response to sending user credentials. In some examples, upload settings may include information pertaining to what, when, where, and/or how the simulation program **300** should upload data to the remote server(s) **114**. In some examples, screen mirroring settings may include information pertaining to what, when, where, and/or how the simulation program **300** should send to and/or display on the remote display(s) **116**.

In the example of FIG. **3**, the simulation program **300** proceeds to block **304** after block **302**. At block **304**, the simulation program **300** determines whether or not to conduct the welding simulation. In some examples, this determination may be based on user input (e.g., selecting to begin simulation), a detected configuration of the workpieces **900** and/or welding tool **700**, a timer, and/or some other appropriate consideration. For example, the simulation program **300** may prompt the user (e.g., via display screen **204** and/or speakers **214**) to hold the trigger **706** for a certain length of time, touch an icon displayed on the screen **204**, and/or provide some other input to begin conducting the welding simulation. As shown, the simulation program **300** proceeds to block **306** if the simulation program determines that the simulation should not yet begin. At block **306** the simulation program **300** either decides to return to block **302** or end the simulation program **300** (e.g., based on a user input to end and/or exit program and/or some other appropriate consideration).

In the example of FIG. **3**, the simulation program **300** proceeds to block **308** after block **304** in response to a determination that a welding simulation should be conducted. In some examples, the simulation program **300** may provide instructions (e.g., via display screen **204** and/or speakers **214**) as to how to setup the weld training system **100** for the simulation prior to actually beginning the simulation at block **308**. For example, the simulation program **300** may output instructions (and/or guidance) as to how to secure the mobile device **200** to the helmet shell **104** and/or torch **700**, and/or how to configure the workpiece(s) **900** prior to actually beginning the simulation at block **308**. In some examples, the instructions may be in the form of one or more images, videos, animations, and/or auditory messages.

In some examples, the instructions (and/or guidance) may be tailored to the user and/or simulation using one or more parameters of the simulation program **300**. For example, the simulation program **300** may output instructions (and/or guidance) as to how to secure the mobile device **200** to the helmet shell **104** in a normal mode of operation, and output instructions (and/or guidance) as to how to secure the mobile device **200** to the torch **700** in a helmet-less mode of operation. In some examples, instructions (and/or guidance) as to how to secure the mobile device **200** to the helmet shell **104** and/or torch **700** may only be provided if the user selects the icon displayed on the screen **204** to start the simulation **300** at block **306**.

At block **308**, the simulation program **300** captures sensor data via the camera sensor(s) **208**, mobile sensors **206**, and/or mounted sensors **106**. For example, image, audio,

thermal, position, movement, angle, and/or other data may be captured. Additionally, at block 308, the simulation program 300 captures data from the welding tool 700. In some examples, this may comprise receiving one or more signals from the communication module 710 of the welding tool 700. In some examples, the communication module 710 may be in electrical and/or mechanical communication with the trigger 706 of the welding tool 700, and/or send one or more signals indicative of the whether the trigger 706 has been and/or is being activated. In some examples, the simulation program 300 may additionally, or alternatively, determine whether the trigger has been and/or is being activated via an analysis of the sensor data (e.g., distance between and/or presence of certain markers 112). Finally, at block 308, the simulation program 300 captures input data from the input devices 218 and/or display screen 204 of the mobile device 200.

In the example of FIG. 3, the simulation program 300 proceeds to block 310 after block 308. At block 310, the simulation program 300 analyzes data obtained at block 308 to determine positions and/or orientations of the welding tool 700, workpiece(s) 900, and/or one or more simulated welding tools 407 and/or simulated workpieces 410. In some examples, the analysis may include analyzing sensor data to recognize markers 112 on the welding tool 700 and/or workpiece(s) 900 and determine the positions and/or orientations of those markers 112 relative to the mobile device 200. In some examples, the analysis may include using image, acoustic, and/or thermal recognition techniques to identify objects proximate to and/or in the FOV 108 of the mobile device 200. In some examples, the analysis may take into account one or more of the simulation parameters of block 302.

In the example of FIG. 3, the simulation program 300 proceeds to block 312 after block 310. At block 312, the simulation program 300 determines an impact to a score and/or grade of the user. For example, the user may start with a score of 0, 50, or 100, and/or a grade of F, C, or A, and the determined position and/or orientation of the welding tool 700 and/or workpiece(s) 900 may impact the grade and/or score. In some examples, the simulation program 300 may take into consideration one or more simulation parameters and/or welding technique parameters when determining the grade/score impact. For example, the simulation program 300 may determine how far from an expected position and/or orientation the welding tool 700 is when determining a score/grade impact. Further, the simulation program 300 may determine the expected position and/or orientation based on the simulation exercise and/or properties of the simulation exercise. As another example, the simulation program 300 may determine a degree to which a deviation and/or adherence to the expected position and/or orientation may impact the score/grade based on the difficulty and/or realism.

In the example of FIG. 3, the simulation program 300 further determines feedback at block 312. For example, the simulation program 300 may determine what actions may be taken by the user to improve their score (e.g., change of equipment parameters, welding technique, position and/or orientation of the welding tool 700 and/or workpiece(s) 900, etc.), and prepare feedback indicative of such actions. In some examples, the simulation program 300 may consider the position and/or orientation of the welding tool 700 and/or workpiece(s) 900 determined at block 310 when determining feedback. In some examples, the simulation program 300 may additionally, or alternatively, consider certain simulation parameters when determining feedback

(e.g., the selected exercise, joint type, tutorial, goal, difficulty, feedback settings, mode, equipment type, equipment parameters, marking parameters, etc.). In some examples, feedback may be comprised of audio and/or visual output of the mobile device 200 and/or welding tool 700. In some examples, feedback may be comprised of vibration output of the mobile device 200 and/or welding tool 700. In some examples, feedback may be comprised of one or more simulated feedback effects.

In the example of FIG. 3, the simulation program 300 also determines one or more simulation effect and/or simulation effect properties at block 312. For example, the simulation program 300 may determine positions, orientations, intensities, and/or other properties of one or more simulated welding effects, simulated feedback effects, simulated interface effects and/or other simulated effects. In some examples, simulated welding effects may include simulated welding arcs, weld puddles, weld beads, welding sounds, welding fumes, and/or vibrations. In some examples, simulated feedback effects may include vibrations, reticles, targets, guides, instructions, scores, grades, markings, and/or other appropriate audio, visual, and/or tactile effects. In some examples, the weld training system 100 may allow a user to add, edit, and/or delete simulated markings, such as described, for example, in U.S. Non-Provisional patent application Ser. No. 16/273,980, filed Feb. 12, 2019, and titled "VIRTUAL MARKINGS IN WELDING SYSTEMS," the entirety of which is hereby incorporated by reference. In some examples, simulated interface effects may include simulated buttons, menus, and/or other appropriate audio, visual, and/or tactile effects that assist a user in controlling and/or interfacing with the configuration parameters and/or settings of the welding simulation. In some examples, other effects may include simulated material overlays (e.g., to make the welding tool 700 and/or workpiece(s) 900 appear more sturdy, heavy, metallic and/or realistic), buttons, instructions, markings, and/or other appropriate audio, visual, and/or tactile effects.

In some examples, certain properties of the simulated effects may be based, at least in part, on the simulation parameters. For example, the simulation program 300 may simulate certain welding effects (e.g., welding arcs, weld puddles, weld beads, welding sounds, welding fumes, vibration) differently depending on a type and/or model of welding-type equipment (e.g., welding-type power supply, wire feeder, gas supply, and/or welding tool 700) selected for the simulation, and/or the selected equipment parameters. In some examples, the simulation program 300 may configure effect properties to be similar to the properties of environmental effects that occur in the real world when welding using the selected equipment with the selected equipment parameters. This may provide a user with a welding experience that more closely adheres to a welding experience that they may experience in the real world using equipment they are familiar with and/or own. In some examples, the realism of the effects may also be impacted by a realism setting.

As another example, the simulation program 300 may simulate the properties of the feedback effects and/or other effects (e.g., reticles, targets, guides, instructions, markings) differently based on a selected exercise, joint type, tutorial, goal, difficulty, feedback setting, realism, mode, and/or marking setting. In some examples, different exercises and/or tutorials may entail welding at different locations with different equipment parameters and/or welding techniques. The simulation program 300 may simulate feedback effects differently to reflect this, such as, for example, by changing

reticles, targets, guides, instructions, markings to indicate to the user the required and/or recommended equipment parameters, welding techniques, and/or positions, orientations, and/or configurations of the workpiece(s) **900** and/or welding tool **700**.

In the example of FIG. 3, the simulation program **300** proceeds to block **314** after block **312**. At block **314**, the simulation program **300** outputs the feedback, simulated effects, and/or grade/score to the user (e.g., via the mobile device **200** and/or welding tool **700**). For example, in an augmented reality simulation, the graphics circuitry **224** (and/or other circuitry) and display screen **204** of the mobile device **200** may generate one or more images that overlay one or more grades/scores, feedback, and/or simulated effects onto one or more images of the user's FOV **108** (e.g., captured by the camera sensor(s) **208**, mounted sensors **106**, and/or mobile sensors **206**). In a virtual reality simulation, the graphics circuitry **224** (and/or other circuitry) and display screen **204** of the mobile device **200** may generate one or more entirely simulated images that include a simulated welding environment, welding tool **700**, welding workpieces **900**, etc., along with one or more grades/scores, feedback, and/or simulated effects. In some examples, the feedback, simulated effects, and/or grade/score may be output to the user via audio and/or tactile output instead of, or in addition to, visual output. In some examples, the simulation program **300** may additionally output an option allowing the user to share an image and/or video of the welding simulation, their weld, their current view, their grade/score, and/or some other aspect of the welding simulation to a social media application.

In the example of FIG. 3, the simulation program **300** proceeds to block **316** after block **314**. At block **316**, the simulation program **300** determines whether the simulation should end or continue. In some examples, the simulation program **300** may make this determination based on whether a user has reached a selected goal and/or completed a selected exercise. In some examples, the determination may be based on whether a user has provided some input indicative of a desire and/or command to stop the simulation. If the simulation program **300** determines that the simulation should stop, the simulation program **300** proceeds to block **306**, which is discussed above. If the simulation program determines that the simulation should continue, the simulation program **300** returns to block **308**.

In some examples, the simulation program **300** may implement changes to the simulation configurations at block **316** if the simulation program **300** determines the simulation should continue. For example, the user may provide one or more inputs indicative of a desire and/or command to change one or more simulation configurations (e.g., exercise, equipment parameters, goals, difficulty, realism, etc.) during the welding simulation. As another example, the simulation program **300** may automatically decide to change one or more simulation parameters. In such examples, the simulation program **300** may implement those changes at block **316** if the simulation program **300** determines the simulation should continue, before returning to block **308**.

FIG. 4a depicts an example display screen **204** of the mobile device **200** during a normal operational mode of the simulation program **300**. As shown, the display screen **204** depicts a simulated welding tool **407** applying a simulated welding arc **402** to a simulated workpiece assembly **410** at an end of a simulated weld bead **404**. A simulated weld puddle **406** and simulated fumes **408** are produced by the simulated welding arc **402**. An arrow **418** is displayed to

give the user feedback as to where they should be welding. A grade **411** and a score **412** are shown at the bottom of the display screen **204**.

In the example of FIG. 4a, interface buttons **414** are shown at the top and bottom of the display screen **204**. In some examples, the buttons **414** may inform a user about, and/or allow a user to select and/or change, certain simulation configuration parameters. In some examples, a user may choose to end the welding simulation by selecting the "End" button **414**. In some examples, a user may choose to share one or more aspects of the welding simulation by selecting the "Share" button **414**. In some examples, the interface buttons **414** may be anchored to the workpiece(s) **900**, and/or a user may select one or more of the interface buttons (and/or provide other input) using the welding tool **700**, such as described, for example, in U.S. Provisional Patent Application No. 62/807,661, filed Feb. 19, 2019, and titled "SYSTEMS FOR SIMULATING JOINING OPERATIONS USING MOBILE DEVICES," the entirety of which is hereby incorporated by reference.

FIG. 4b depicts an example display screen **204** of the mobile device **200** during a tool-less mode of the simulation program **300**. In some examples, the welding simulation program **300** may operate without a welding tool **700** during a tool-less mode of operation. Instead of using a welding tool **700**, in some examples, a user may use their finger(s) and/or stylus to deliver touch screen inputs and/or perform the welding simulation during a tool-less mode of operation. In the example of FIG. 4b, a user's hand **416** is providing touch input to the display screen **204** to indicate where a simulated welding arc **402** should be applied to a simulated workpiece assembly **410**. In such an example, the simulation program **300** may capture touch input from the display screen **204** of the mobile device **200** at block **308** and use that input to determine positions and/or orientations of a simulated welding tool **407** at block **310**, and/or simulated effects at block **312**.

In some examples, different touch input may be interpreted differently by the simulation program **300**. For example, one finger input may be interpreted as a command to move the simulated welding tool to a selected portion of the display screen **204**. On the other hand, two finger input may be interpreted as a command to begin welding (e.g., activate the simulated welding tool **407**), such as, for example, where the simulated welding tool **407** is already positioned, or at the selected portion of the display screen **204**.

In some examples, a user may hold the mobile device **200** in their hand, during a tool-less mode of operation, rather than the mobile device **200** being held by the mobile device mount **102**. In some examples, one or more physical workpieces **900** may still be used during the tool-less mode of operation. In some examples, no workpiece(s) **900** or workpiece assemblies **1000** may be used during the tool-less mode of operation, and the simulation program **300** may simply generate one or more simulated workpiece assemblies **410** on its own.

FIG. 4c is an example depiction of a mobile device **200** mounted to a welding tool **700** during a helmet-less mode of the simulation program **300**. In some examples, the simulation program **300** may operate without the helmet shell **104** during the helmet-less mode of operation. In some examples, mounting the mobile device **200** to the welding tool **700** may allow an operator to use the welding tool **700** and/or workpiece(s) **900** in a quasi-normal operation of the simulation program **300**, but without having to mount the

mobile device 200 to a helmet shell 200 or having to hold the mobile device 200 themselves.

In the example of FIG. 4c, the mobile device 200 is mounted to the welding tool 700 using a tool mount 450. In some examples, the tool mount 450 may be similar (or identical) to the device mount 102. In the example of FIG. 4c, the tool mount 450 comprises a clamp 452 that secures the tool mount 450 to the welding tool 700, and a cradle 454 having brackets 456 that holds the mobile device 200. In some examples, the cradle 454 may be considered part of the mobile device 200. In some examples, the device mount 102 may be used as part or all of the cradle 454. In some examples, the clamp 452 may comprise one or more magnets, adhesives, and/or other additional securement devices. In some examples, the clamp 452 of the tool mount 450 may be omitted and/or integrated into the welding tool 700 itself (e.g., at the handle 704).

While not shown due to the perspective of the drawing, in some examples, the cradle 454 may further include a base configured to support the mobile device 200. While not shown due to the perspective of the drawing, in some examples, the cradle 454 (e.g., at the base) may be attached to the clamp 452 via a mechanical link. In some examples, the mechanical link may comprise a flexible cable, a gooseneck, an arm, a joint (e.g., a ball joint), a ratcheting mechanism, and/or other means by which to movably connect the cradle 454 to the clamp 452. In some examples, the mechanical link is configured to allow the cradle 454 to be repositioned with respect to the clamp 452 and/or welding tool 700, so that the position, orientation, and/or FOV 108 of the mobile device 200 may be adjusted.

In some examples, the simulation program 300 may provide a preview of the impact of certain feedback setting(s) and/or other simulation parameters. For example, the display screen 204 may show a preview 499 of feedback effects that might be shown during the simulation program 300 under the selected feedback setting(s). In some examples, such a preview 499 might be shown when setting and/or changing feedback settings and/or other simulation parameters (e.g., at blocks 302 and/or 316). FIGS. 4d-4f show examples of such previews 499 shown on an example display screen 204 of the mobile device 200.

In the examples of FIGS. 4d-4f, the display screen 204 depicts an options panel 498 having several interface buttons 414. Interface buttons 414a, 414b, 414c, and 414d are feedback guide settings for work angle, travel angle, contact to work distance (CTWD), and travel speed guides, respectively. Interface buttons 414e and 414f correspond to simulation exercise settings for push and drag welds, respectively. Interface buttons 414g and 414h correspond to user characteristic settings for right and left handedness, respectively. Interface button 414i allows a user to select all the guides.

In the example of FIGS. 4d-4f, the display screen 204 also depicts a preview 499 above the options panel 498. As shown, the preview 499 includes a depiction of a simulated welding tool 407, along with sample guides 496a, 496b, 496c, and 496d. In some examples, each sample guide 496 corresponds to one of the feedback guide setting buttons 414a, 414b, 414c, and 414d. Thus, a particular sample guide 496 is shown in the preview 499 when its corresponding feedback guide setting button 414 is selected, and not shown in the preview 499 when its corresponding feedback guide setting button 414 is not selected.

In FIG. 4d, all the feedback guide setting buttons 414a, 414b, 414c, and 414d are shown as selected. Likewise, all the sample guides 496a, 496b, 496c, and 496d are shown in

the preview 499. In FIG. 4e, the work angle button 414a and travel speed button 414d have been deselected, while the travel angle button 414b and CTWD button 414c remain selected. Accordingly, the preview 499 depicts the sample guide 496b and sample guide 496c, but not the sample guide 496a or sample guide 496d. In FIG. 4f, the opposite is true; the work angle button 414a and travel speed button 414d are selected, while the travel angle button 414b and CTWD button 414c have been deselected. Accordingly, the preview 499 depicts the sample guide 496a and sample guide 496d, but not the sample guide 496b or sample guide 496c.

In the examples of FIGS. 4d-4f, the depictions of both the preview 499 and the simulation exercise setting buttons 414e and 414f are dependent on the selection of the characteristic setting buttons 414g/h for right and left handedness. In the examples of FIGS. 4d and 4e, the right handed characteristic setting button 414g is selected, and so both the preview 499 and simulation exercise setting buttons 414e and 414f are depicted in a right handed orientation. However, in FIG. 4f, the left handed characteristic setting button 414h is selected, and so both the preview 499 and the simulation exercise setting buttons 414e and 414f are depicted in a left handed orientation. While shown as a static image in the examples of FIGS. 4d-4f, in some examples, the preview 499 may be an animation or video, such as a video of a previously recorded simulation. In some examples, the depictions of the preview 499 and/or the simulation exercise setting buttons 414e/f may assist a user in quickly understanding how feedback, user characteristic, simulation exercise, and/or other settings might impact the simulation program 300.

FIG. 5 is a flowchart illustrating an example temperature detection process 500. In some examples, the temperature detection process 500 may alter operation of the welding simulation program 300 and/or mobile device 200 if/when the operating temperature of the mobile device 200 exceeds a threshold. In some examples, the temperature detection process 500 may comprise machine readable instructions stored by the memory circuitry 226 of the mobile device 200. In some examples, the temperature detection process 500 may be part of the welding simulation program 300. For example, the temperature detection process 500 may execute during the preliminary configuration block 302 of the simulation program 300, and/or when the simulation loop recurs at block 316. In some examples, the temperature detection process 500 may execute independently of the welding simulation program 300, such as, for example, before, during, and/or after the execution of the welding simulation program 300.

In the example of FIG. 5, the temperature detection process 500 begins at block 502. At block 502, the temperature detection process 500 determines a temperature of the mobile device 200 and/or one or more components of the mobile device 200. In some examples, the temperature detection process 500 may determine the temperature via the mounted sensors 106 of the mobile device mount 102 and/or the mobile sensors 206 of the mobile device 200. In some examples, mobile sensors 206 and/or mounted sensors 106 may be positioned and/or configured to detect an overall temperature of the mobile device 200, and/or a particular temperature of one or more particular components of the mobile device 200. For example, the mobile device 200 may have one or more internal mobile temperature sensors 206 positioned and/or configured to measure a temperature proximate the processing circuitry 222, graphics circuitry 224, communication circuitry 210, memory circuitry 226, and/or other components of the mobile device 200. As

another example, the mobile sensors **206** and/or mounted sensors **106** may be positioned and/or configured to measure an overall temperature of the mobile device **200** as a whole.

In the example of FIG. 5, the temperature detection process **500** proceeds to block **504** after block **502**. At block **504**, the temperature detection process **500** determines whether one or more temperatures measured at block **502** are less than one or more first temperature thresholds. In some examples, the first temperature threshold(s) may be representative of one or more temperatures below which there is little risk of thermal damage to the mobile device **200**. In some examples, the first temperature threshold(s) may be predetermined and/or stored in the memory circuitry **226**. In some examples, one or more of the temperature threshold may be set by a user, such as, for example, during block **302** of the welding simulation program **300**. In some examples, the temperature detection process **500** may consider multiple first temperature thresholds at block **504**. For example, the memory circuitry **226** may store different first temperature thresholds for the mobile device **200** as a whole and the individual components of the mobile device **200** (e.g., the processing circuitry **222**, the graphics circuitry **224**, etc.).

In the example of FIG. 5, the temperature detection process **500** proceeds to block **506** after block **504** if the temperature detection process **500** determines one or more measured temperatures are below the first temperature threshold(s). In some examples, the temperature detection process **500** proceeds to block **506** after block **504** only if the temperature of the mobile device **200** as a whole and the temperature of all of its individual components are all less than (or equal to) the first temperature threshold(s). In some examples, the temperature detection process **500** proceeds to block **506** after block **504** if the temperature of the mobile device **200** as a whole or the temperature of any of its individual components are less than (or equal to) the first temperature threshold(s).

At block **506**, the temperature detection process **500** sets (or returns) the mobile device **200** and/or simulation program **300** (and/or related settings) to regular, default, and/or peak operation. In some examples, this may comprise setting, resetting, and/or increasing one or more performance and/or graphical settings of the mobile device **200** and/or simulation program **300**, and/or one or more related settings (e.g., realism, resolution, etc.). In some examples, this may comprise enabling and/or resuming uploads to the remote server(s) **114**, mirroring done by the remote display(s) **116**, the welding simulation blocks **308** and/or **316**, and/or the simulation program **300** in general. As shown, the temperature detection process **500** ends after block **506**, though, in some examples, the temperature detection process **500** may instead return to block **502** instead of ending.

In the example of FIG. 5, the temperature detection process **500** proceeds to block **508** after block **504** if the temperature detection process **500** determines that one or more measured temperatures are not below the first temperature threshold(s). At block **508**, the temperature detection process **500** determines whether one or more temperatures measured at block **502** are greater than one or more second temperature thresholds. In some examples, the second temperature threshold(s) may be the same or higher than the first temperature threshold(s). In some examples, the second temperature threshold(s) may be representative of one or more temperatures above which there is non-trivial and/or substantial risk of thermal damage to the mobile device **200**. In some examples, one or more of the second temperature thresholds may be predetermined and/or stored

in the memory circuitry **226**. In some examples, one or more of the second temperature thresholds may be set by a user, such as, for example, during block **302** of the welding simulation program **300**. In some examples, the temperature detection process **500** may consider multiple second temperature thresholds at block **508**. For example, the memory circuitry **226** may store different second temperature thresholds for the mobile device **200** as a whole and the individual components of the mobile device **200** (e.g., the processing circuitry **222**, the graphics circuitry **224**).

In the example of FIG. 5, the temperature detection process **500** ends after block **508** if the measured temperature of the mobile device **200** and/or its components are less than their respective second temperature thresholds. In some examples, the temperature detection process **500** ends if the measured temperature of the mobile device **200** and/or its individual components are less than or equal to their respective second temperature thresholds. In some examples, the temperature detection process **500** ends only if the temperature of the mobile device **200** as a whole and the temperature of all of its individual components are all less than (or equal to) their respective second temperature thresholds. In some examples, the temperature detection process **500** ends if the temperature of the mobile device **200** as a whole or the temperature of any of its individual components are less than (or equal to) their respective second temperature threshold. While shown as ending in the example of FIG. 5, in some examples, the temperature detection process **500** may instead return to block **502** instead of ending.

In the example of FIG. 5, the temperature detection process **500** proceeds to block **510** after block **508** in response to determining the temperature of the mobile device **200** as a whole and/or the temperature of all or some of its individual components are greater than or equal to their respective second temperature thresholds. At block **510**, the temperature detection process **500** outputs one or more notifications. In some examples, the notification(s) may be output via the light(s) **202**, speaker(s) **214**, display screen **204**, and/or any other output device(s) **216** of the mobile device **200**. In some examples, the notification(s) may be output via a speaker, light, vibration device, and/or other output device of the welding tool **700**. In some examples, the notification(s) may include one or more symbols, icons, messages (e.g., visual and/or audio), animations, vibrations, and/or light flashes. For example, the welding tool **700** and/or mobile device **200** may vibrate to indicate that one or more temperatures have exceeded the threshold(s). As another example, speech may play from the welding tool **700** and/or mobile device **200** telling the user that one or more temperatures have exceeded the threshold(s), and/or how to reduce the temperature(s). As another example, an icon, symbol, text message, one or more pictures, a video, and/or an animation may be shown via the display screen **204** of the mobile device telling the user that one or more temperatures have exceeded the threshold(s), and/or how to reduce the temperature(s). In some examples, the notification may include an output (such as discussed above) indicating that the welding simulation will be terminated, disabled, and/or prevented from running until the temperature(s) are reduced.

In the example of FIG. 5, the temperature detection process **500** proceeds to block **512** after block **510**. In some examples, block **510** may instead be skipped and/or omitted. In such an example, the temperature detection process **500** may proceed to block **512** after block **508** if the temperature

detection process **500** determines that the temperature(s) measured at block **502** is/are greater than the second temperature threshold(s).

At block **512**, the temperature detection process **500** determines whether the one or more temperatures measured at block **502** are greater than one or more third temperature thresholds. In some examples, the third temperature threshold(s) may be the same or higher than the second temperature threshold(s). In some examples, the third temperature threshold(s) may be representative of one or more temperatures above which there is significant and/or immediate risk of thermal damage to the mobile device **200**. In some examples, one or more of the third temperature thresholds may be predetermined and/or stored in the memory circuitry **226**. In some examples, one or more of the third temperature thresholds may be set by a user, such as, for example, during block **302** of the welding simulation program **300**. In some examples, the temperature detection process **500** may consider multiple third temperature thresholds at block **510**. For example, the memory circuitry **226** may store different third temperature thresholds for the mobile device **200** as a whole and the individual components of the mobile device **200** (e.g., the processing circuitry **222**, the graphics circuitry **224**).

In the example of FIG. **5**, the temperature detection process **500** ends after block **512** if the measured temperature of the mobile device **200** and/or its components are less than their respective third temperature thresholds. In some examples, the temperature detection process **500** ends if the measured temperature of the mobile device **200** and/or its individual components are less than or equal to their respective third temperature thresholds. In some examples, the temperature detection process **500** ends only if the temperature of the mobile device **200** as a whole and the temperature of all of its individual components are all less than (or equal to) their respective third temperature thresholds. In some examples, the temperature detection process **500** ends if the temperature of the mobile device **200** as a whole or the temperature of any of its individual components are less than (or equal to) their respective third temperature threshold. While shown as ending in the example of FIG. **5**, in some examples, the temperature detection process **500** may instead return to block **502** instead of ending.

In the example of FIG. **5**, the temperature detection process **500** proceeds to block **514** after block **512** in response to determining the temperature of the mobile device **200** as a whole and/or the temperature of all or some of its individual components are greater than or equal to their respective third temperature thresholds. At block **514**, the temperature detection process **500** alters an operation, parameter, setting, configuration, and/or other aspect of the mobile device **200** and/or simulation program **300** to reduce a temperature of the mobile device **200** and/or one or components of the mobile device **200**. In some examples, the alteration(s) may comprise a decrease in a performance and/or graphical setting of the mobile device **200** and/or simulation program **300**, and/or a related setting (e.g., realism, resolution, etc.). In some examples, the alteration(s) may comprise turning off and/or stopping uploads to the remote server(s) **114**, to lessen the work required by the communication circuitry **210**. In some examples, the alteration(s) may comprise turning off and/or terminating any mirroring being done on the remote display(s) **116** to lessen the work required by the communication circuitry **210** and/or graphics circuitry **224**. In some examples, the alteration(s) may comprise terminating the simulation program **300** entirely, and/or prohibiting the simulation program **300**

from beginning the welding simulation at block **308** and/or continuing the welding simulation at block **316**. In some examples, the alteration(s) may comprise powering down the mobile device **200**. While the example of FIG. **5** shows the temperature detection process **500** ending after block **514**, in some examples, the temperature detection process **500** may instead return to block **502** instead of ending.

FIG. **6** is a flowchart illustrating an example orientation configuration process **600**. In some examples, the orientation configuration process **600** may determine whether a current orientation of the mobile device **200** should be changed before beginning the welding simulation. In some examples, the orientation configuration process **600** may comprise machine readable instructions stored by the memory circuitry **226** of the mobile device **200**. In some examples, the orientation configuration process **600** may execute as part of the welding simulation program **300**. For example, the orientation configuration process **600** may execute during the preliminary configuration block **302** of the simulation program **300** and/or when the simulation loop recurs at block **316**. In some examples, the orientation configuration process **600** may execute independently of the welding simulation program **300**, such as, for example, before execution of the welding simulation program **300**. In some examples, the orientation configuration process **600** may only execute during a normal mode of operation.

In the example of FIG. **6**, the orientation configuration process **600** begins at block **602**. At block **602**, the orientation configuration process **600** determines a current orientation (e.g., left or right landscape) of the mobile device **200** within the mobile device mount **102**. In some examples, this orientation determination may include and/or entail receiving some input from the user (e.g., via welding tool **700** and/or one of the input devices **218**) identifying the orientation of the mobile device **200**. In some examples, this determination may include and/or entail evaluating one or more measurements and/or outputs of the camera sensor(s) **208**, mobile sensor(s) **206**, and/or mount sensor(s) **106**. For example, the orientation configuration process **600** may evaluate magnetometer, accelerometer, IMU, and/or other sensor data to determine the orientation of the mobile device **200**.

In some examples, the mobile device **200** may undergo a calibration step prior to the orientation configuration process **600**, where sensor data from the camera sensor(s) **208**, mobile sensor(s) **206**, and/or mount sensor(s) **106** is evaluated in different orientations of the mobile device **200** and/or associated with the different orientations of the mobile device when stored in memory circuitry **226**. In such an example, the orientation configuration process **600** may compare instantaneous data from of the camera sensor(s) **208**, mobile sensor(s) **206**, and/or mount sensor(s) **106** with the stored data to determine the most likely orientation of the mobile device **200**. In some examples, the sensor data and orientation association(s) may be predefined and/or predetermined. For example, the sensor data and orientation association(s) may be downloaded from the remote server(s) **114** and/or queried from memory circuitry **226** (e.g., based on some identifying information of the mobile device **200**, such as a make, model, serial number, etc.).

In some examples, the orientation configuration process **600** may evaluate sensor data from interactions and/or communications between the mobile sensor(s) **206** and/or mount sensor(s) **106** to determine an orientation of the mobile device **200**. For example, the mobile device mount **102** may include one or more mounted sensors **106** (e.g., NFC and/or RFID sensors) positioned at different portions

of the device mount **102**. In such an example, the mounted sensor(s) **106** may be configured to sense, detect, communicate with, and/or otherwise interface with one or more mobile sensors **206** of the mobile device **200** when the mobile sensor(s) **206** and mounted sensor(s) **106** are in proximity to one another. In some examples, certain mobile sensors **206** and mounted sensors **106** may only be in such proximity when the mobile device **200** is in a particular orientation. In some examples, a calibration step and/or loading of calibration data may be performed prior to this sort of orientation determination, similar to that discussed above.

In the example of FIG. **6**, the orientation configuration process **600** proceeds to block **604** from block **602**. At block **604**, the orientation configuration process **600** determines an operational orientation of the mobile device **200**. In some examples, determination of the operational orientation may be based on one or more user characteristics (e.g., dominant user hand). In some examples, the user characteristic(s) may be determined via manual input from the user (e.g., selection of one or more options via the welding tool **700** and/or input device **218** of mobile device **200**), loading of the user characteristic(s) from memory circuitry **226**, and/or download of the user characteristic(s) from the remote server(s) **114**.

In some examples, the user characteristic(s) may be automatically determined by the orientation configuration process **600**. For example, the orientation configuration process **600** may determine the user characteristic(s) based on certain user behaviors observed during the welding simulation. In some examples, data from the mounted sensors **106** and/or the mobile sensors **206** may show that a user exhibits welding behavior indicative of one or more particular user characteristics. For example, data from the mounted sensors **106** and/or the mobile sensors **206** may show that a user positions the welding tool **700** relative to the workpiece assembly **1000** in a certain way and/or a certain orientation at the start and/or end of a particular type of welding that is indicative of a particular user characteristic. For example, the orientation configuration process **600** may determine that a user is right handed if data from the mounted sensor(s) **106**, camera sensor(s) **208**, and/or mobile sensor(s) **206** show that the user positions the welding tool **700** to the right of the workpiece assembly **1000** when beginning a push welding technique, and/or positions the welding tool **700** to the left of the workpiece assembly **1000** when beginning a drag welding technique.

In some examples, the orientation configuration process **600** may determine the user characteristic(s) based on data from the mounted sensor(s) **106**, camera sensor(s) **208**, and/or mobile sensor(s) **206** relating to the welding tool **700**, and/or markers **112** on the welding tool **700**. For example, the orientation configuration process **600** may analyze and/or evaluate (e.g., image) data captured by the mounted sensor(s) **106**, camera sensor(s) **208**, and/or mobile sensor(s) **206** to determine whether the markers **112** on the welding tool **700** are relatively discernable, clear, and/or perpendicular to the camera sensor(s) **208**. In some examples, the orientation configuration process **600** may further consider the current orientation of the mobile device **200** determined at block **602** when determining the user characteristic(s) and/or operational orientation. For example, the orientation configuration process **600** may analyze and/or evaluate the sensor data and determine that the markers **112** on the welding are not discernable, clear, and/or perpendicular to the camera sensor(s) **208**. The orientation configuration process **600** may further determine that the current mobile

device **200** orientation (determined at block **602**), in conjunction with the determination that the markers **112** are less than discernable, clear, and/or perpendicular, suggests a particular user characteristic (e.g., right handed). Further, the orientation configuration process **600** may determine that, in view of the user characteristic and the current orientation of the mobile device **200**, the operational orientation of the mobile device **200** during the welding simulation should be a different orientation.

FIGS. **7a-7b** illustrate different perspectives of a welding tool **700**, such as may be captured, for example, by a camera sensor **208** of the mobile device **200** when the mobile device is mounted in different orientations. In the example of FIG. **7a**, the welding tool **700** appears oriented substantially parallel to the viewer. While some of the markers **112** on the nozzle **702** are somewhat visible, most of the markers **112** are completely invisible due to the orientation of the welding tool **700**. Additionally, the profile of the welding tool **700** itself is difficult to discern. Indeed, were the welding tool **700** tilted farther forward in the example of FIG. **7a**, none of the markers **112** might be visible and the visible profile of the welding tool **700** would be even less.

In the example of FIG. **7b**, the welding tool **700** is oriented more perpendicular to the viewer, such that a substantial side and/or perspective profile of the welding tool **700** is relatively apparent. More markers **112** on the nozzle **702** of the welding tool **700** are clear and visible than in FIG. **7a**. The markers **112**, and the profile of the welding tool **700**, are also more perpendicular to the viewer. Were the welding tool **700** to tilt forward or backward (as may occur during welding), the markers **112** on the welding tool **700** would still be visible. Additionally, the profile of the welding tool **700** and/or features of the welding tool **700** (e.g., the nozzle **702**, neck **708**, handle **704**, trigger **706**, logo **712**, etc.) would still be visible.

In some examples, the memory circuitry **226** of the mobile device **200** may store information relating to the markers **112** of the welding tool **700** (e.g., number, shape, size, pattern, position, etc.). In some examples, the memory circuitry **226** may store other data relating to the welding tool **700**, such as, for example, one or more images, models, and/or diagrams of the welding tool **700** and/or its shape, features, dimensions, and/or other characteristics. In some examples, the orientation configuration process **600** may compare the stored information to the information obtained from the mounted sensor(s) **106**, camera sensor(s) **208**, and/or other mobile sensor(s) **206** to determine the user characteristic.

For example, the orientation configuration process **600** may determine that the welding tool **700** is oriented similarly to FIG. **7a** relative to the camera sensor(s) **208** based on an analysis of the sensor data. Further, the current orientation of the mobile device **200** determined at block **602** may be a right landscape orientation, with the camera sensor(s) **208** facing outwards from the mobile device mount **102** through the right aperture **110a** rather than the left aperture **110b**. In such an example, the orientation configuration process **600** may determine that the user is right handed. Further, the orientation configuration process **600** may determine that the operational orientation of the mobile device **200** should be a left landscape orientation (e.g., with the camera sensor(s) **208** facing outwards from the mobile device mount **102** through the left aperture **110b**, based on the determined user characteristic (i.e., right handedness), as that would provide a clearer and/or more perpendicular view of the welding tool **700** and/or markers **112** (similar to FIG. **7b**).

In the example of FIG. 6, the orientation configuration process 600 proceeds to block 606 after block 604. At block 606, the orientation configuration process 600 determines whether the current orientation of the mobile device 200 determined at block 602 is the same as the operational orientation determined at block 604. If so, the orientation configuration process 600 proceeds to block 608, where the orientation configuration process 600 returns and/or executes the welding simulation (e.g., at block 302 of the program 300) then ends. If not, the orientation configuration process 600 proceeds to block 610, where the orientation configuration process 600 outputs one or more notifications to the user, then ends. However, in some examples, the orientation configuration process 600 may return to the beginning at block 602 after block 610, rather than ending.

In some examples, the notification(s) output at block 610 may be output via the speaker(s) 214, display screen 204, and/or output device(s) 216 of the mobile device 200. In some examples, the notification(s) output at block 610 may be output via a speaker and/or vibration device of the welding tool 700. In some examples, the notification(s) may include one or more arrows, icons, messages (e.g., visual and/or audio), animations, vibrations, and/or light flashes. For example, the welding tool 700 and/or mobile device 200 may vibrate to indicate that the orientation should change, and/or speech may play from the welding tool 700 and/or mobile device 200 telling the user that the orientation should be changed and/or providing instructions on how to change the orientation. As another example, an icon, arrow, text message, one or more pictures, a video, and/or an animation may be shown via the display screen 204 of the mobile device telling the user that the orientation should be changed and/or providing instructions on how to change the orientation. In some examples, the notification may include an output (such as discussed above) indicating that the welding simulation will be terminated, disabled, and/or prevented from running until the orientation is changed. In some examples, the orientation configuration process 600 may interface with the simulation program 300 to prevent execution of the welding simulation until the orientation is changed. In some examples, the notification(s) may indicate that (and/or how) an orientation (and/or other configuration) of the device mount 102 may be changed in order to change an orientation of the mobile device 200.

FIG. 8 is a flowchart illustrating an example workpiece configuration process 800. In some examples, the workpiece configuration process 800 may detect and/or determine a spatial relationship between two or more workpieces 900 based on data from the camera sensor(s) 208, mobile sensor(s) 206 and/or mounted sensor(s) 106. In some examples, the workpiece configuration process 800 may comprise machine readable instructions stored by the memory circuitry 226 of the mobile device 200. In some examples, the workpiece configuration process 800 may execute as part of the welding simulation program 300. For example, the workpiece configuration process 800 may execute during the preliminary configuration block 302 of the simulation program 300 and/or when the simulation loop recurs at block 316. In some examples, the workpiece configuration process 800 may execute independently of the welding simulation program 300, such as, for example, before execution of the welding simulation program 300.

In the example of FIG. 8, the workpiece configuration process 800 begins at block 802. At block 802, the workpiece configuration process 800 determines a spatial relationship (e.g., relative positions and/or orientations) between two or more workpieces 900. In some examples, the work-

piece configuration process 800 may determine the spatial relationship based on data from the camera sensor(s) 208, mobile sensor(s) 206, and/or mounted sensor(s) 106. For example, the workpiece configuration process 800 may analyze and/or evaluate the data in an attempt to recognize features and/or characteristics of a workpiece 900, such as, for example, one or more markers 112 (and/or the absence of one or more markers 112). In some examples, the memory circuitry 226 may include and/or store images, models, diagrams, and/or other data relating to known features and/or characteristics of certain workpieces 900. Such features and/or characteristics may include, for example, types, positions, orientations, patterns, shapes, dimensions, numbers, arrangements, colors, and/or other properties of the markers 112 on the workpieces 900. In some examples, the features and/or characteristics may include, for example, one or more dimensions, profiles, shapes, and/or other properties of the workpieces 900 themselves. In some examples, the workpiece configuration process 800 may additionally consider the position and/or orientation of the mobile device 200 (and therefore the user) relative to the workpiece(s) 900 when determining the spatial relationship between the two or more workpieces 900.

In the example of FIG. 8, the workpiece configuration process 800 proceeds to block 804 after block 802. At block 804, the workpiece configuration process 800 determines whether the spatial relationship between two or more workpieces 900 is such that a joint and/or intersection has been formed between the two or more workpieces 900. Obviously, in examples where the workpiece configuration process 800 fails to recognize at least two workpieces 900 at block 802, the workpiece configuration process 800 will determine there is no joint or intersection between two or more workpieces 900. In some examples, the workpiece configuration process 800 may detect and/or recognize two or more workpieces 900 within the FOV 108 and/or vicinity of the mobile device 200, yet still fail to detect and/or recognize a joint and/or intersection between the two or more workpieces 900. For example, the two or more workpieces 900 may instead be separated by some distance, rather than intersecting. In the example of FIG. 8, the workpiece configuration process 800 proceeds to block 810 (discussed below) if the workpiece configuration process 800 determines that no joint and/or intersection has been formed between two or more workpieces 900.

In the example of FIG. 8, the workpiece configuration process 800 proceeds to block 806 after block 804 if the workpiece configuration process 800 determines that one or more joints and/or intersections have been formed between two or more workpieces 900. At block 806, the workpiece configuration process 800 determines what type of intersection(s) and/or joint(s) are formed by the two or more workpieces 900. For example, a joint may be lap joint, a butt joint, a corner joint, a T joint, an edge joint, a pipe joint, and/or some other type of joint.

In some examples, the determination of the type(s) of joint(s) and/or intersection(s) may be based on data from the camera sensor(s) 208, mobile sensor(s) 206, and/or mount sensor(s) relating to features and/or characteristics of the workpieces 900. In some examples, the determination of the type(s) of joint(s) and/or intersection(s) may additionally be based on data stored in memory circuitry 226 relating to features and/or characteristics of known workpieces 900, workpieces assemblies 1000, and/or joints formed between workpieces 900 to form one or more workpiece assemblies 1000. For example, the workpiece configuration process 800 may analyze and/or evaluate the sensor data collected by the

camera sensor(s) **208**, mobile sensor(s) **206**, and/or mounted sensor(s) **106** and compare that sensor data to the data stored in memory circuitry **226** in an attempt to recognize one or more types of joints and/or intersections. In some examples, the stored data may be stored by and/or retrieved from the remote server(s) **116** instead of, or in addition to, the memory circuitry **226**.

In some examples, the stored data may include, for example, images, models, diagrams, and/or other data relating to features and/or characteristics of known workpieces **900**, workpieces assemblies **1000**, and/or joints. In some examples, the features and/or characteristics may include the presence and/or absence of one or more markers **112**. In some examples, the features and/or characteristics may include types, positions, orientations, patterns, shapes, dimensions, numbers, arrangements, colors, and/or other properties of the markers **112** on the workpieces **900**. In some examples, the features and/or characteristics may include dimensions, profiles, shapes, and/or other properties of the workpieces **900** themselves. In some examples, the features and/or characteristics may include dimensions, profiles, shapes, and/or other properties of various workpiece assemblies **1000** that may be formed by combinations of workpieces **900**. In some examples, the features and/or characteristics may include dimensions, profiles, shapes, and/or other properties of various joints that may be formed between workpieces **900** to create the workpiece assemblies **1000**.

In the example of FIG. **8**, the workpiece configuration process **800** proceeds to block **808** after block **806**. At block **808**, the workpiece configuration process **800** determines whether the joint type(s) determined at block **806** match one or more expected joint types. In some examples, the workpiece configuration process **800** may determine the one or more expected joint types based on one or more simulation parameters (e.g., exercise(s), joint type(s), difficulty, etc.). In some examples, there may be no expected joint type and/or the expected joint type(s) may be any joint type.

In some examples, block **808** is satisfied if there is at least one joint type determined at block **806** for each expected joint type. In some examples, the number of joint types must match the exact same number of expected joint types (e.g., 6 lap joints=6 expected lap joints) for block **806** to be satisfied. In some examples, block **806** may also be satisfied if the number of joint types is more than the number of expected joint types (e.g., 8 lap joints >6 expected lap joints).

In the example of FIG. **8**, the workpiece configuration process **800** proceeds to block **812** if the joint type(s) determined at block **806** match the expected joint type(s) at block **808**. At block **812**, the workpiece configuration process **800** returns and/or executes the welding simulation (e.g., at block **302** of the program **300**). In some examples, the welding simulation may execute using the joint type(s) determined by the workpiece configuration process **800**. In some examples, the workpiece configuration process **800** may also interface with the welding simulation program **300** to record a positive impact on the score/grade of the user at block **812**, and/or output a notification to that effect. In the example of FIG. **8**, the workpiece configuration process **800** ends after block **812**. However, in some examples, the workpiece configuration process **800** may return to block **802** after block **812** instead of ending.

In the example of FIG. **8**, the workpiece configuration process **800** proceeds to block **810** if the joint type(s) determined at block **806** do not match the expected joint type(s) at block **808**, or if the workpiece configuration

process **800** determines that there are no joints at block **804**. At block **810**, the workpiece configuration process **800** outputs a notification. In some examples, the workpiece configuration process **800** may also interface with the welding simulation program **300** to record a negative impact on the score/grade of the user at block **810**, and/or output a notification to that effect. In some examples, a magnitude of the negative impact may be influenced by a degree of difference between the expected joint(s) and the determined joint(s), and/or whether there was any joint at all. As shown, after block **810**, the workpiece configuration process **800** ends. However, in some examples, the orientation configuration process **600** may return to the beginning at block **802** after block **810**, rather than ending.

In some examples, the notification(s) output at block **810** and/or **812** may be output via the speaker(s) **214**, display screen **204**, and/or output device(s) **216** of the mobile device **200**. In some examples, the notification(s) may be output via a speaker and/or vibration device of the welding tool **700**. In some examples, the notification(s) may include one or more arrows, icons, messages (e.g., visual and/or audio), animations, vibrations, and/or light flashes. For example, the welding tool **700** and/or mobile device **200** may vibrate to indicate that there are no recognized joints or that one or more of the recognized joints are different than the expected joint(s). As another example, speech may play from the welding tool **700** and/or mobile device **200** telling the user that the workpieces **900** should be rearranged (and/or how they should be rearranged) to produce an expected joint changed and/or workpiece assembly **1000**. As another example, an icon, arrow, text message, one or more pictures, a video, and/or an animation may be shown via the display screen **204** of the mobile device telling the user that the workpieces **900** should be rearranged (and/or how they should be rearranged). In some examples, the notification may include an output (such as discussed above) indicating that the welding simulation will be terminated, disabled, and/or prevented from running until the workpieces **900** are rearranged. In some examples, the workpiece configuration process **800** may interface with the simulation program **300** to prevent execution of the welding simulation until the orientation is changed.

FIGS. **9a-9f** depict example modular workpieces **900** that may be used with the weld training system **100**. FIGS. **9a-9d** depict substantially flat, cuboid, workpieces **900**. FIG. **9e** depicts a cylindrical workpiece **900**. FIG. **9f** shows a more irregularly shaped workpiece **900**. In some examples, each modular workpiece **900** may include and/or be configured with one or more connectors **902** that enable the modular workpiece **900** to be tool-lessly connected and/or disconnected to another modular workpiece **900** to form a workpiece assembly **1000**. FIGS. **10a-10f** show example workpiece assemblies **1000** that may be constructed from the various workpieces **900**. In some examples, each modular workpiece **900** may include and/or be configured with one or more fixture couplers **904** that enable the modular workpiece **900** to be tool-lessly connected and/or disconnected to a fixturing system **1100**. FIGS. **11a-11c** show example fixturing systems **1100** that may be used to capture and/or retain workpiece assemblies **1000**.

In some examples, a connector **902** may be a magnet (north or south polarity), an electromagnet, a ferromagnetic material, a hook fastener, a loop fastener, a snap fastener, a button, a clamping fastener, a prong, a stud, an aperture, a socket, and/or some other type of tool-less connector. In some examples, tool-less connectors **902** may be advantageous because they can be easily connected to and/or

engaged with other connectors **902** without the need for auxiliary tools (e.g., screwdrivers, hammers, etc.). Tool-less connectors **902** may also be advantageous over adhesives, as the tool-less connectors **902** may be continually connected, disconnected, and reconnected with negligible change to their effectiveness, unlike adhesives.

FIG. **9a** shows an example modular workpiece **900a**. As shown, the workpiece **900a** is a substantially flat, cuboid, object. The workpiece **900a** has a substantially flat upper surface **906** on which markers **112** are disposed. While hidden in the example of FIG. **9a**, the workpiece **900a** also has a lower surface opposite the upper surface **906**. Several sidewalls **908** of the workpiece **900a** connect the upper surface **906** and lower surface.

In the example of FIG. **9a**, a fixture coupler **904** is disposed on a sidewall **908** of the workpiece **900a**. As shown, the coupler **904** on the workpiece **900** is an aperture. However, in some examples, the coupler **904** may be any of the tool-less type connectors **902** described above. In some examples, the coupler **904** may be configured to tool-lessly engage with, and/or disengage from, a complementary coupler **904** of a fixturing system **1100**, so as to hold the workpiece **900a** in place for simulated welding.

In the example of FIG. **9a**, arrays of connectors **902** are distributed along two opposite edges of the upper surface **906**. Connectors **902** are also arrayed along an edge of the lower surface, substantially aligned with those on the upper surface **906**. While hidden in the example of FIG. **9a**, an array of connectors **902** may also be distributed along an opposite edge of the lower surface. In some examples, markers **112** may also be disposed on the lower surface. In some examples, arrays of connectors **902** may be distributed along the other edges of the workpiece **900** as well. In some examples, fewer connectors **902** may be distributed along the workpiece **900**.

In the example of FIG. **9a**, the connectors **902** along each edge are substantially evenly spaced and/or symmetrical. In some examples, this may allow each and/or any array of connectors **902** on the workpiece **900a** to be used with any other workpiece **900** with a similar array of connectors **902**. Thus, two workpieces **900a** may be connected together in several different ways to form several different joints, such as, for example, the lap joint workpiece assembly **1000a** shown in FIG. **10a**.

FIG. **9b** shows another example modular workpiece **900b**. As shown, the workpiece **900b** is also a substantially flat, cuboid, object. The workpiece **900b** also has a substantially flat upper surface **906** on which markers **112** are disposed, and a sidewall **908** on which a coupler **904** is disposed. An array of connectors **902** are also substantially evenly distributed along an edge of the upper surface **906**.

However, unlike the workpiece **900a**, the workpiece **900b** has no markers **112** across an approximate middle of the workpiece **900b** in the example of FIG. **9b**. Instead, an array of connectors **902** are distributed across the middle of the workpiece **900**. The markers **112** have been removed across the middle to allow for another workpiece **900** to be connected across the middle. Nevertheless, in some examples, markers **112** may be disposed across the middle over or under the connectors **902**. FIG. **9d** shows a workpiece **900d** with connectors across the middle arrayed in a substantially symmetrical arrangement underneath (and/or hidden by) the markers **112**.

In the example of FIG. **9b**, the connectors **902** are asymmetrically and/or unevenly distributed across the middle of the workpiece **900b** in a poka yoke arrangement. In some examples, this asymmetric and/or poka yoke

arrangement of connectors **902** may allow only connection to workpieces **900** with complementary arrangements of connectors **902**. Additionally, the asymmetry may ensure the workpieces **900** only connect together in a particular configuration and/or orientation, thereby preventing unintended and/or incorrect arrangements and/or connections.

FIG. **9c** shows a workpiece **900c** that is similar to workpiece **900a**. However, instead of connectors **902** arrayed along edges of the upper surface **906** and lower surface, workpiece **900c** has connectors **902** arrayed along a sidewall **908** of the workpiece **900c**. While only shown on one sidewall **908** in the example of FIG. **9c**, in some examples, the connectors **902** may be arrayed along several sidewalls **908**. The connectors **902** are also arranged asymmetrically, similar to workpiece **900b**.

Given the complementary arrangement of connectors **902** in workpiece **900b** and workpiece **900c**, in some examples, the two workpieces **900** may connect together to form a T joint workpiece assembly **1000b**. Such a T joint workpiece assembly **1000b** is shown, for example, in FIG. **10b**. In some examples, two workpieces **900c** may connect together along the sidewalls **908** to form an edge joint workpiece assembly **1000c**, such as shown, for example in FIG. **10c**. In some examples, the connectors **902** on the sidewall **908** of workpiece **900c** (and/or along a different sidewall **908**) may be symmetrically arranged more like those of workpiece **900a**, so that a connection with workpiece **900a** may be possible to form a butt joint and/or corner joint, such as shown in the workpiece assembly **1000d** of FIG. **10d**. While the workpieces **900a-d** in FIGS. **9a-9d** are each shown with distinct arrangements to illustrate certain concepts, in some examples, a single workpiece **900** may include and/or combine two or more of these arrangements.

FIG. **9e** shows a cylindrical workpiece **900e** with connectors arranged in a circular pattern on its upper surface **906**. While not shown due to the viewpoint of FIG. **9e**, in some examples a similar arrangement (and/or a different arrangement) of connectors **902** may be arranged on a lower surface of the workpiece **900e**, and/or on the sidewall **908** of the workpiece **900e**. With such an arrangement of connectors **902**, the workpieces **900** may be stacked to form a pipe joint workpiece assembly **1000e**, such as shown, for example, in FIG. **10e**.

While FIGS. **9a-9e** show conventional shaped workpieces **900**, in some examples, the weld training system **100** may include irregularly and/or unconventionally shaped workpieces. FIG. **9f** depicts an example of an irregularly shaped workpiece **900f**. As shown, the workpiece **900f** is somewhat wave shaped, with connectors **902** arranged on an upper surface. In some examples, connectors **902** may also be arranged on the sidewalls **908**. FIG. **10f** shows an irregular workpiece assembly **100f** formed from two workpieces **900f**. Other workpiece **900** and/or workpiece assembly **1000** shapes and/or configurations are also contemplated by this disclosure. While FIGS. **10a-10f** show workpiece assemblies **100** comprising two connected workpieces **900**, in some examples, a workpiece assembly may comprise three or more connected workpieces **900**.

FIGS. **11a-11b** depict an example fixturing system **1100a**. In some examples, the fixturing system **1100a** may be configured to retain one or more workpieces **900** and/or workpiece assemblies **1000** in various positions, such as for welding, observation, inspection, temporary storage, and/or other appropriate activities. FIG. **11a** shows the fixturing system **1100a** in a disengaged position, where no workpiece assembly **1000** is retained by the fixturing system **1100**. FIG.

11*b* shows the fixturing system 1100*a* in an engaged position where the fixturing system 1100*a* retains a workpiece assembly 1000 in a fixed position.

In the examples of FIGS. 11*a*-11*b*, the fixturing system 1100 includes two movable retainers 1102. Each retainer 1102 has a body 1106 attached to a coupler 1104. As shown, the coupler 1104 of each retainer 1102 is a prong. However, in some examples, the coupler 1104 may be any of the tool-less type connectors described above. In some examples, the coupler 1104 may be configured to tool-lessly engage with, and/or disengage from, a complementary coupler 904 on a workpiece 900, so as to hold the workpiece 900 in a fixed position for simulated welding.

In the example of FIGS. 11*a*-11*b*, each retainer 1102 of the fixturing system 1100 is linked to a fixture 1108 through a linking mechanism. In some examples, the fixture 1108 may be a tube, pipe, stanchion, table, platform, wall, and/or other appropriate surface. As shown, the linking mechanism includes a fixture clamp 1110 connected to the fixture 1108 and a retainer clamp 1112 connected to the retainer body 1106. The fixture clamp 1110 and retainer clamp 1112 are connected to one another through a mechanical link 1114. In some examples, the connection of the fixture clamp 1110 to the fixture 1108 may be loosened and/or tightened, such as, by example, loosening and/or tightening the fixture clamp 1110 via a tightening mechanism (not shown). By loosening and/or tightening the fixture clamps 1110, the retainers 1102 may be moved apart to allow a workpiece 900 and/or workpiece assembly 1000 to be put in place (e.g., as shown in FIG. 11*a*), then moved back together to retain the workpiece 900 and/or workpiece assembly 1000 via the couplers 1104 (e.g., as shown in FIG. 11*b*).

FIG. 11*c* shows an example of an alternative fixturing system 1100*b*. In the example of FIG. 11*c*, the fixture clamps 1110 are part of the retainer bodies 1106, and the retainer clamps 1112 and link 1114 are omitted. As shown, the tightening mechanism 1116 is also in mechanical communication with the retainer bodies 1106 and, through them, the fixture clamps 1110.

FIG. 12 is a flowchart illustrating an example equipment configuration process 1200. In some examples, the equipment configuration process 1200 may generate a simulated equipment interface that replicates an appearance of an actual equipment interface corresponding to a selected piece of welding-type equipment. In some examples, the equipment configuration process 1200 may additionally allow the user to select equipment parameters that may be used to conduct the welding simulation via the simulated equipment interface. In some examples, the equipment configuration process 1200 may comprise machine readable instructions stored by the memory circuitry 226 of the mobile device 200. In some examples, the equipment configuration process 1200 may be part of the welding simulation program 300. For example, the equipment configuration process 1200 may execute during the preliminary configuration block 302 of the simulation program 300, and/or during the welding simulation. In some examples, the equipment configuration process 1200 may execute independently of the welding simulation program 300, such as, for example, before, during, and/or after the execution of the welding simulation program 300.

In the example of FIG. 12, the equipment configuration process 1200 begins at block 1202. At block 1202, the equipment configuration process 1200 determines what welding-type equipment may be selected for the welding simulation. In some examples, this determination may be based on certain user information, such as, for example,

what equipment the user currently uses, has previously purchased, and/or is authorized to use for the welding simulation. In some examples, this user information may be stored in memory circuitry 226 and/or received from the remote server(s) 114 (e.g., in response to one or more signals and/or queries). In some examples, the determination may be based on one or more simulation parameters (e.g., exercise, difficulty, realism, user characteristics, etc.).

In the example of FIG. 12, the equipment configuration process 1200 proceeds to block 1204 after block 1202. At block 1204, the equipment configuration process 1200 automatically selects, or allows a user to select, a piece of welding-type equipment. In some examples, the equipment configuration process 1200 may automatically select the welding-type equipment when there is only one appropriate option, such as, for example, when a selected simulation parameter (e.g., exercise) dictates that a particular piece of welding-type equipment be used, or when the user information only allows for one particular piece of welding-type equipment. In some examples, the equipment configuration process 1200 may automatically select a default piece of welding even if there are multiple appropriate options, and let the user decide whether to keep or change the default welding-type equipment.

In some examples, the equipment configuration process 1200 may allow a user to select the welding-type equipment using the welding tool 700, display screen 204, one or more input devices 218, mobile sensors 206, camera sensors 208, and/or other appropriate mechanisms. In some examples, the equipment configuration process 1200 may allow a user to select the welding-type equipment via a dropdown menu 1302 displayed to the user, such as shown in FIG. 13, for example. For example, the equipment configuration process 1200 may display the dropdown menu 1302, and the user may use speech, the welding tool 700, and/or some other means to make selections. In some examples, the equipment configuration process 1200 may allow the user to select the welding-type equipment by entering an identifier (e.g., serial number) of a real piece of welding-type equipment, scanning a graphical indicia (e.g., QR code, barcode, etc.) having identifying information of a real piece of welding-type equipment encoded, taking a picture of a real piece of welding-type equipment, and/or some other means. In some examples, the equipment configuration process 1200 may prohibit selection of welding-type equipment determined not to be available at block 1202.

In the example of FIG. 12, the equipment configuration process 1200 proceeds to block 1206 after block 1204. At block 1206, the equipment configuration process 1200 checks to make sure the selected welding-type equipment is one of the pieces of welding-type equipment determined to be available at block 1202. If not, the equipment configuration process 1200 returns to block 1204. If so, the equipment configuration process 1200 proceeds to block 1208.

In the example of FIG. 12, the equipment configuration process 1200 displays on the display screen 204 of the mobile device 200 a simulated equipment interface 1304 that replicates the appearance of an actual equipment interface 1404 of the selected welding-type equipment. In some examples, this replication may help orient a user who is already familiar with the actual interface 1404 of the selected welding-type equipment, thereby making them more comfortable with the welding simulation. In some examples, the replication may help familiarize users with new welding-type equipment interfaces if the selected welding-type equipment is not one with which they are already readily familiar. While described as being displayed on the

display screen **204** of the mobile device, in some examples, the simulated equipment interface **1304** may instead be displayed on the display screen(s) **204** of the desktop device **250**.

FIG. **13** shows an example of a simulated equipment interface **1304** displayed on the display screen **204** of the mobile device **200**. As shown, the user has selected an AX1 Welder as the equipment. FIG. **14** shows an example of an actual AX1 Welder **1400**, with its actual equipment interface **1404**. As shown, the simulated equipment interface **1304** replicates an actual equipment interface **1404** of the AX1 Welder **1400**, with simulated buttons, options, and display screens, as well as a simulated dial. In some examples, the user may use the simulated equipment interface **1304** to select equipment parameters to use in the welding simulation.

In some examples, the equipment configuration process **1200** may additionally provide one or more recommendations to the user (e.g., via the display screen **204** and/or speaker(s) **214**) based on the selected welding-type equipment. For example, the equipment configuration process **1200** may recommend equipment parameters (e.g., gas type, wire type, etc.) and/or complementary welding-type equipment based on the selected welding-type equipment. In some examples, the equipment configuration process **1200** may store (e.g., in memory circuitry **226**) recommended equipment parameters associated with certain welding-type equipment and/or other simulation parameters (e.g., exercise, realism, difficult, goals, etc.), and query the stored recommendations. In some examples, the equipment configuration process **1200** may receive recommendations from the remote server(s) **114** (e.g., in response to one or more similar queries and/or signals). In the example of FIG. **13** the equipment configuration process **1200** has displayed a recommendation message **1306** recommended a certain wire type for the selected welding-type equipment.

In the example of FIG. **12**, the equipment configuration process **1200** proceeds to block **1210** after block **1208**. At block **1210**, the equipment configuration process **1200** receives the equipment parameters from the user via the simulated equipment interface **1304**. In some examples, the equipment configuration process **1200** may also receive other selections from the user at block **1210**. For example, a user may select to receive more information about the welding-type equipment they have selected. In the example of FIG. **13**, the display screen **204** displays a link **1308** to an informational page (e.g., online and/or locally stored) where the user may access more information about the selected welding-type equipment. In some examples, selection of this link **1308** may direct the user to an informational page that is also a purchasing page where the selected welding-type equipment, a recommended (or other) consumable (e.g., wire, gas, contact tip, etc.), complementary welding-type equipment, and/or other items may be purchased.

In the example of FIG. **12**, the equipment configuration process **1200** proceeds to block **1212** after block **1210**. At block **1212** the equipment configuration process **1200** determines whether the user has selected the link **1308**. If so, the equipment configuration process **1200** proceeds to block **1214**, where the user is taken to the informational and/or purchasing page associated with the link **1308**. If the user does not select the link **1308** (or when the user has finished with the informational/purchasing page), the equipment configuration process **1200** proceeds to block **1218**.

In the example of FIG. **12**, the equipment configuration process **1200** determines whether the user has finished entering equipment parameters at block **1218**. In some

examples, the equipment configuration process **1200** may determine the user has finished when the user makes an explicit selection that they have finished (e.g., by selecting the “Done” icon **1310** in FIG. **13**). In some examples, the equipment configuration process **1200** may determine the user has finished when all or a sufficient number of equipment parameters have been entered. In some examples, the sufficient number may be based on other simulation parameters (e.g., exercise, goal, user characteristics etc.). In some examples, the equipment configuration process **1200** may prohibit finishing until all or a sufficient number of equipment parameters have been entered. In the example of FIG. **12**, the equipment configuration process **1200** returns to block **1210** if the equipment configuration process **1200** determines the user has not finished entering equipment parameters.

In the example of FIG. **12**, the equipment configuration process **1200** proceeds to block **1220** if the equipment configuration process **1200** determines the user has finished entering equipment parameters. At block **1220** the equipment configuration process **1200** either returns to the main welding simulation program **300**, where a welding simulation may be run using the selected equipment parameters, or begins the welding simulation itself using the selected equipment parameters. As shown, the equipment configuration process **1200** ends after block **1220**.

The present disclosure contemplates using mobile devices **200** (and/or desktop devices **250**) to conduct welding simulations. In some examples, it may be advantageous to use mobile devices **200** due to their availability, relative affordability, and/or technical power. The disclosure further contemplates automatically detecting whether an orientation of the mobile device **200** is proper for the simulation, and notifying the user if not.

The present disclosure additionally contemplates using modular workpieces **900** for conducting welding simulations. In some examples, the modular workpieces **900** may be configured to tool-lessly connect to, and/or disconnect from, other modular workpieces **900** to form various workpiece assemblies **1000**. In some examples, tool-less connectors **902** may be advantageous because they can be easily connected to and/or engaged with other connectors **902** without the need for auxiliary tools (e.g., screwdrivers, hammers, etc.). Tool-less connectors **902** may also be advantageous over adhesives, as the tool-less connectors **902** may be continually connected, disconnected, and reconnected with negligible change to their effectiveness, unlike adhesives. In some examples, the welding simulation may further be configured to recognize different joints formed by the modular workpieces **900**, and conduct the welding simulation accordingly.

The present disclosure further contemplates using simulated equipment interfaces **1304** that replicate the appearance of actual equipment interfaces **1404** of actual welding-type equipment. In some examples, this replication may help orient a user who is already familiar with a particular piece of welding-type equipment and/or its actual equipment interface **1404**, thereby making them more comfortable with the welding simulation. In some examples, the replication may help users who are unfamiliar with a particular piece of welding-type equipment become familiar with the welding-type equipment (and/or its actual equipment interface **1404**). Additionally, the present disclosure contemplates simulating certain welding effects in accordance with the way the effects might occur in the real world when real welding is performed using the real world welding-type equipment.

The present method and/or system may be realized in hardware, software, or a combination of hardware and software. The present methods and/or systems may be realized in a centralized fashion in at least one computing system, or in a distributed fashion where different elements are spread across several interconnected computing or cloud systems. Some examples may comprise a non-transitory machine-readable (e.g., computer readable) medium (e.g., FLASH drive, optical disk, magnetic storage disk, or the like) having stored thereon one or more lines of code executable by a machine, thereby causing the machine to perform processes as described herein.

While the present method and/or system has been described with reference to certain examples, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the present method and/or system. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from its scope. Therefore, it is intended that the present method and/or system not be limited to the particular examples disclosed, but that the present method and/or system will include all implementations falling within the scope of the appended claims.

As used herein, “and/or” means any one or more of the items in the list joined by “and/or”. As an example, “x and/or y” means any element of the three-element set $\{(x), (y), (x, y)\}$. In other words, “x and/or y” means “one or both of x and y”. As another example, “x, y, and/or z” means any element of the seven-element set $\{(x), (y), (z), (x, y), (x, z), (y, z), (x, y, z)\}$. In other words, “x, y and/or z” means “one or more of x, y and z”.

As utilized herein, the terms “e.g.,” and “for example” set off lists of one or more non-limiting examples, instances, or illustrations.

As used herein, the terms “coupled,” “coupled to,” and “coupled with,” each mean a structural and/or electrical connection, whether attached, affixed, connected, joined, fastened, linked, and/or otherwise secured. As used herein, the term “attach” means to affix, couple, connect, join, fasten, link, and/or otherwise secure. As used herein, the term “connect” means to attach, affix, couple, join, fasten, link, and/or otherwise secure.

As used herein, “mobile device” or “mobile electronic device” refers to a handheld electronic computing apparatus having a casing that houses a camera, a display screen, processing circuitry, and communication circuitry in a single unit.

As used herein, “desktop device” or “desktop electronic device” refers to a non-handheld electronic computing apparatus that houses processing circuitry, communication circuitry, and possibly a display in a single unit, while also controlling (and/or powering) a camera and a display that are housed in a separate unit (e.g., a helmet shell) outside of the single unit of the non-handheld electronic computing apparatus.

As used herein the terms “circuits” and “circuitry” refer to physical electronic components (i.e., hardware) and any software and/or firmware (“code”) which may configure the hardware, be executed by the hardware, and or otherwise be associated with the hardware. As used herein, for example, a particular processor and memory may comprise a first “circuit” when executing a first one or more lines of code and may comprise a second “circuit” when executing a second one or more lines of code. As utilized herein, circuitry is “operable” and/or “configured” to perform a function whenever the circuitry comprises the necessary

hardware and/or code (if any is necessary) to perform the function, regardless of whether performance of the function is disabled or enabled (e.g., by a user-configurable setting, factory trim, etc.).

As used herein, a control circuit may include digital and/or analog circuitry, discrete and/or integrated circuitry, microprocessors, DSPs, etc., software, hardware and/or firmware, located on one or more boards, that form part or all of a controller, and/or are used to control a welding process, and/or a device such as a power source or wire feeder.

As used herein, the term “processor” means processing devices, apparatus, programs, circuits, components, systems, and subsystems, whether implemented in hardware, tangibly embodied software, or both, and whether or not it is programmable. The term “processor” as used herein includes, but is not limited to, one or more computing devices, hardwired circuits, signal-modifying devices and systems, devices and machines for controlling systems, central processing units, programmable devices and systems, field-programmable gate arrays, application-specific integrated circuits, systems on a chip, systems comprising discrete elements and/or circuits, state machines, virtual machines, data processors, processing facilities, and combinations of any of the foregoing. The processor may be, for example, any type of general purpose microprocessor or microcontroller, a digital signal processing (DSP) processor, an application-specific integrated circuit (ASIC), a graphic processing unit (GPU), a reduced instruction set computer (RISC) processor with an advanced RISC machine (ARM) core, etc. The processor may be coupled to, and/or integrated with a memory device.

As used, herein, the term “memory” and/or “memory circuitry” means computer hardware or circuitry to store information for use by a processor and/or other digital device. The memory and/or memory circuitry can be any suitable type of computer memory or any other type of electronic storage medium, such as, for example, read-only memory (ROM), random access memory (RAM), cache memory, compact disc read-only memory (CDROM), electro-optical memory, magneto-optical memory, programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically-erasable programmable read-only memory (EEPROM), a computer-readable medium, or the like. Memory can include, for example, a non-transitory memory, a non-transitory processor readable medium, a non-transitory computer readable medium, non-volatile memory, dynamic RAM (DRAM), volatile memory, ferroelectric RAM (FRAM), first-in-first-out (FIFO) memory, last-in-first-out (LIFO) memory, stack memory, non-volatile RAM (NVRAM), static RAM (SRAM), a cache, a buffer, a semiconductor memory, a magnetic memory, an optical memory, a flash memory, a flash card, a compact flash card, memory cards, secure digital memory cards, a microcard, a minicard, an expansion card, a smart card, a memory stick, a multimedia card, a picture card, flash storage, a subscriber identity module (SIM) card, a hard drive (HDD), a solid state drive (SSD), etc. The memory can be configured to store code, instructions, applications, software, firmware and/or data, and may be external, internal, or both with respect to the processor.

As used herein, welding-type refers to welding, cladding, brazing, plasma cutting, induction heating, carbon arc cutting, and/or hot wire welding/preheating (including laser welding and laser cladding), carbon arc cutting or gouging, and/or resistive preheating.

As used herein, welding-type power refers power suitable for welding, cladding, brazing, plasma cutting, induction heating, carbon arc cutting, and/or hot wire welding/preheating (including laser welding and laser cladding), carbon arc cutting or gouging, and/or resistive preheating.

As used herein, a welding-type power supply and/or power source refers to any device capable of, when power is applied thereto, supplying welding, cladding, brazing, plasma cutting, induction heating, laser (including laser welding, laser hybrid, and laser cladding), carbon arc cutting or gouging, and/or resistive preheating, including but not limited to transformer-rectifiers, inverters, converters, resonant power supplies, quasi-resonant power supplies, switch-mode power supplies, etc., as well as control circuitry and other ancillary circuitry associated therewith.

Disabling of circuitry, actuators, hardware, and/or software may be done via hardware, software (including firmware), or a combination of hardware and software, and may include physical disconnection, de-energization, and/or a software control that restricts commands from being implemented to activate the circuitry, actuators, hardware, and/or software. Similarly, enabling of circuitry, actuators, hardware, and/or software may be done via hardware, software (including firmware), or a combination of hardware and software, using the same mechanisms used for disabling.

What is claimed is:

1. A weld training system, comprising:
 - a mobile electronic device configured to conduct a weld training simulation, the mobile electronic device comprising:
 - a display screen,
 - processing circuitry, and
 - memory circuitry comprising computer readable instructions which, when executed by the processing circuitry, cause the processing circuitry to:
 - select a piece of welding-type equipment from several pieces of welding-type equipment,
 - select one or more simulation parameters, and
 - simulate a welding arc, a weld puddle, a weld bead, a welding sound, or a welding fume via the weld training simulation based on the piece of welding-type equipment that was selected and the one or more simulation parameters that were selected,
 - the welding arc, the weld puddle, the weld bead, the welding sound, or the welding fume being simulated differently than if a different piece of welding-type equipment had been selected and an identical set of the one or more simulation parameters had been selected.
2. The system of claim 1, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, cause the processing circuitry to display, on the display screen, a simulated welding-type equipment interface based on the piece of welding-type equipment that was selected, wherein the simulated welding-type equipment interface replicates an appearance of an actual equipment interface of the piece of welding-type equipment.
3. The system of claim 1, wherein the one or more simulation parameters comprise one or more of a welding process, a welding current, a welding voltage, a pulse frequency, a gas type, a gas pressure, a wire type, wire diameter, a wire feed speed, a workpiece material type, or a workpiece material thickness, and the piece of welding-type equipment comprises a welding-type power supply, a gas supply, or a wire feeder, or a welding tool.

4. The system of claim 1, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, cause the processing circuitry to:

5 select the piece of welding-type equipment based on machine-readable indicia encoding equipment identifying information, the machine-readable indicia comprising graphical indicia encoding equipment identifying information, or

10 select the piece of welding-type equipment based on an image of the piece of welding-type equipment captured by a camera of the mobile electronic device.

5. The system of claim 1, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to provide a recommendation of a welding consumable or complementary welding-type equipment based on the piece of welding-type equipment that was selected or a simulation parameter of the one or more simulation parameters, the simulation parameter comprising a realism setting of the weld training simulation, a difficulty setting of the weld training simulation, or a simulation goal.

6. The system of claim 5, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to display, on the display screen, an option to purchase the piece of welding-type equipment, welding consumable, or complementary welding-type equipment, and the option to purchase comprises a link to a purchase page where the piece of welding-type equipment, welding consumable, or complementary welding-type equipment can be purchased.

7. The system of claim 1, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, cause the processing circuitry to simulate an intensity of the welding arc, the weld puddle, the weld bead, the welding sound, or the welding fume based on the piece of welding-type equipment and the one or more simulation parameters that were selected, the intensity of the welding arc, the weld puddle, the weld bead, the welding sound, or the welding fume being simulated differently than if the different piece of welding-type equipment had been selected and the identical set of the one or more simulation parameters had been selected.

8. The system of claim 1, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to:

50 identify one or more available pieces of welding-type equipment that are available for selection, or one or more unavailable pieces of welding-type equipment that are unavailable for selection, based on a simulation exercise assigned to the user, one or more simulation exercises previously completed by the user, one or more scores previously achieved by the user, a dominant hand of the user, a height of the user, a realism setting of the weld training simulation, or a difficulty setting of the weld training simulation, and prohibit selection of a prohibited piece of welding-type equipment in response to the one or more unavailable pieces of welding-type equipment including the prohibited piece of welding-type equipment, or the one or more available pieces of welding-type equipment not including the prohibited piece of welding-type equipment.

9. The system of claim 1, wherein the welding simulation simulates the welding arc, the weld puddle, the weld bead,

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the welding sound, or the welding fume based on that which would occur in the real world when welding using the piece of welding-type equipment that was selected.

10. The system of claim 1, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to:

identify one or more available pieces of welding-type equipment that are available for selection, or one or more unavailable pieces of welding-type equipment that are unavailable for selection, based on what equipment a user currently uses, what equipment the user has previously purchased, or what equipment the user is authorized to use for the welding simulation, and

prohibit selection of a prohibited piece of welding-type equipment in response to the one or more unavailable pieces of welding-type equipment including the prohibited piece of welding-type equipment, or the one or more available pieces of welding-type equipment not including the prohibited piece of welding-type equipment.

11. A mobile electronic device configured to conduct a weld training simulation, the mobile electronic device comprising:

a display screen;

processing circuitry; and

memory circuitry comprising computer readable instructions which, when executed by the processing circuitry, cause the processing circuitry to:

select a piece of welding-type equipment from several pieces of welding-type equipment,

select one or more simulation parameters, and

simulate a welding arc, a weld puddle, a weld bead, a welding sound, or a welding fume via the weld training simulation based on the piece of welding-type equipment that was selected and the one or more simulation parameters that were selected,

the welding arc, the weld puddle, the weld bead, the welding sound, or the welding fume being simulated differently than if a different piece of welding-type equipment had been selected and an identical set of the one or more simulation parameters had been selected.

12. The mobile electronic device of claim 11, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, cause the processing circuitry to display, on the display screen, a simulated welding-type equipment interface based on the piece of welding-type equipment that was selected, wherein the simulated welding-type equipment interface replicates an appearance of an actual equipment interface of the piece of welding-type equipment.

13. The mobile electronic device of claim 11, wherein the one or more simulation parameters comprise one or more of a welding process, a welding current, a welding voltage, a pulse frequency, a gas type, a gas pressure, a wire type, wire diameter, a wire feed speed, a workpiece material type, or a workpiece material thickness, and the piece of welding-type equipment comprises a welding-type power supply, a gas supply, or a wire feeder, or a welding tool.

14. The mobile electronic device of claim 11, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, cause the processing circuitry to:

select the piece of welding-type equipment based on machine-readable indicia encoding equipment identi-

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fying information, the machine-readable indicia comprising graphical indicia, or select the piece of welding-type equipment based on an image of the piece of welding-type equipment captured by a camera of the mobile electronic device.

15. The mobile electronic device of claim 11, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to provide a recommendation of a welding consumable or complementary welding-type equipment based on the piece of welding-type equipment that was selected and a simulation parameter of the one or more simulation parameters, the simulation parameter comprising a realism setting of the weld training simulation, a difficulty setting of the weld training simulation, or a simulation goal.

16. The mobile electronic device of claim 11, wherein the weld training simulation simulates the welding sound or the welding fume based on the piece of welding-type equipment that was selected.

17. The mobile electronic device of claim 11, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, cause the processing circuitry to simulate an intensity of the welding arc, the weld puddle, the weld bead, the welding sound, or the welding fume based on the piece of welding-type equipment and the one or more simulation parameters that were selected, the intensity of the welding arc, the weld puddle, the weld bead, the welding sound, or the welding fume being simulated differently than if the different piece of welding-type equipment had been selected and the identical set of the one or more simulation parameters had been selected.

18. The mobile electronic device of claim 11, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to:

identify one or more available pieces of welding-type equipment that are available for selection, or one or more unavailable pieces of welding-type equipment that are unavailable for selection, based on a simulation exercise assigned to the user, one or more simulation exercises previously completed by the user, one or more scores previously achieved by the user, a dominant hand of the user, a height of the user, a realism setting of the weld training simulation, or a difficulty setting of the weld training simulation, and

prohibit selection of a prohibited piece of welding-type equipment in response to the one or more unavailable pieces of welding-type equipment including the prohibited piece of welding-type equipment, or the one or more available pieces of welding-type equipment not including the prohibited piece of welding-type equipment.

19. The mobile electronic device of claim 11, wherein the welding simulation simulates the welding arc, the weld puddle, the weld bead, the welding sound, or the welding fume based on that which would occur in the real world when welding using the piece of welding-type equipment that was selected.

20. The mobile electronic device of claim 11, wherein the memory circuitry comprises computer readable instructions which, when executed by the processing circuitry, further cause the processing circuitry to:

identify one or more available pieces of welding-type equipment that are available for selection, or one or more unavailable pieces of welding-type equipment

that are unavailable for selection, based on what equip-
ment a user currently uses, what equipment the user has
previously purchased, or what equipment the user is
authorized to use for the welding simulation, and
prohibit selection of a prohibited piece of welding-type 5
equipment in response to the one or more unavailable
pieces of welding-type equipment including the pro-
hibited piece of welding-type equipment, or the one or
more available pieces of welding-type equipment not
including the prohibited piece of welding-type equip- 10
ment.

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